FOREWORD

This book is Volume 4 of four volumes comprising Chapter XXXIX of Part Two of the Report of the New England-New York Inter-Agency Committee, organized by direction of the President of the United States for the purpose of making a comprehensive survey of the land, water and related resources of the New England-New York Region.

The complete report comprises three parts:

Part One - The General Report.

Part Two - The Technical Report, with detailed studies of the river basins and special subjects.

Part Three - Reference Data.

NOTE

Chapter XXXIX, Special Subjects, Regional, is divided into four volumes:

Volume 1. Fisheries. Wetlands.

Volume 2. Mapping. Mineral Commodities.

Volume 3. Mineral Commodities.

Volume 4. Hurricanes.

THE RESOURCES

OF THE

NEW ENGLAND-NEW YORK REGION

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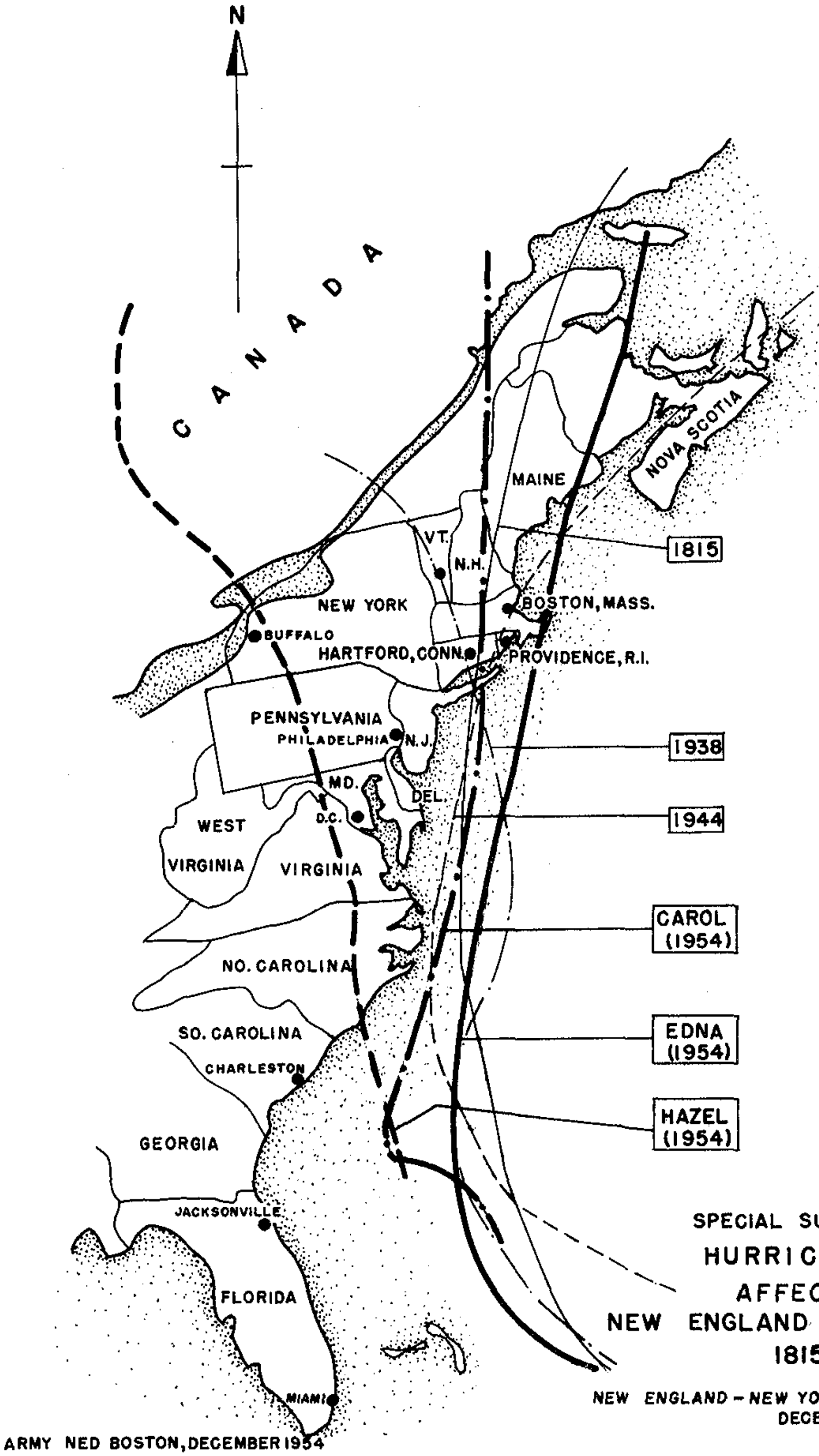
Part Two



SPECIAL SUBJECTS-REGIONAL

HURRICANE PATHS AFFECTING THE NEW ENGLAND NEW YORK REGION 1815, 1938, 1954

NEW ENGLAND - NEW YORK INTER-AGENCY COMMITTEE
DECEMBER 1954

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CHAPTER XXXIX

THE RESOURCES
OF THE
NEW ENGLAND-NEW YORK REGION

PART TWO

CHAPTER XXXIX

SPECIAL SUBJECTS REGIONAL

HURRICANES

VOLUME 4
(of 4 volumes)

NEW ENGLAND - NEW YORK INTER-AGENCY COMMITTEE

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SECTION XXXII - HURRICANES

INTRODUCTION

1. Purpose. - The purpose of this section is to present the results of studies of the disastrous hurricanes occurring in the New England-New York Region in 1954 and prior years. The section develops the following information:

a. An inventory of damages caused by the three 1954 hurricanes, especially damage resulting from coincidental tidal flooding and interior river flooding.

b. A discussion of the determination of a frequency factor, or percentage chance of hurricane occurrence, in the areas concerned.

c. A brief history of prior hurricanes in the area.

d. A discussion of general preventive measures that might be taken to minimize future damages.

e. A discussion of specific protective measures that might be taken to protect, so far as practicable, concentrated areas of high valuation.

2. Scope. - The study is in sufficient detail to delineate the general nature and extent of damages caused by hurricanes which occurred in various portions of the region on August 31 (Hurricane Carol), September 11 (Hurricane Edna), and October 16, 1954 (Hurricane Hazel). Damages in the portions of New England and New York State which were subjected to cyclonic storms of hurricane intensity

in 1938, 1944, and 1954 are described. Damage figures for 1954 hurricanes have been obtained through independent investigations of affected coastal areas by trained personnel, and through correspondence with State officials, and representatives of industry and commerce.

3. Problems of establishing preventive and protective measures are described generally. Subsequent detailed reports offering proposed projects for construction in specific localities may be undertaken by the affected States. Federal study of specific protective projects or active participation in protective work by appropriate Federal agencies, over and beyond the scope of this section, would have required greater time and funds than were available. The conduct by Federal agencies of detailed studies for specific works to protect against hurricane damages would require specific Congressional authorization.

CHARACTERISTICS OF HURRICANES

4. Definition. - Hurricanes are the most destructive of all storms when fully developed. These gigantic storms are inward-spiraling whirls of air which form over tropical waters. Once formed, northern hemisphere hurricanes often enter more northerly latitudes before their dissipation or metamorphosis into an ordinary extra-tropical

storm. The destructiveness of a hurricane results from the wind, which may exceed 100 miles per hour, the rain, which in some hurricanes is of torrential flood-producing proportions, and the sea, which rises before the wind.

5. The wind in a hurricane increases in speed progressively as it spirals inward from the ill-defined periphery to very close to the edge of the eye 1/. Inside the zone of maximum wind is the eye, a region of light wind or, occasionally, dead calm. The shift from full hurricane wind to the light wind of the eye is abrupt as a hurricane passes over. The eye of a mature storm may have a diameter of from 10 to 30 miles or more. To the rear of the eye the wind increases again, but blows in the opposite direction to that in the advance sector. Usually the second blow does not have the intensity of the first. The winds of a hurricane are accompanied by gray skies covered by ragged clouds and driving heavy rain. Thunder and lightning are uncommon. Frequentyly the rain is very heavy in the forward half and more moderate or even light in the rear half. In the eye, there is no rain and the sky may be clear.

6. Origin. - Among the necessary conditions for hurricane formation are: intense sunshine; a more or less uniform area of high humidity and temperature, and low surface friction; a region

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1/ For a detailed discussion of wind behavior in a hurricane refer to Hydrometeorological Report No. 26, U. S. Weather Bureau, Department of Commerce.

and season where the vertical distribution of air temperature is not such as to inhibit vertical air motions; and the deflective force occasioned by the rotation of the earth. These conditions are fulfilled in low latitudes over the oceans as the heat equator swings north of the geographical equator in response to the northward migration of the sun's vertical rays. Hurricanes cannot form close to the geographical equator, where the deflective force of earth rotation is zero.

7. The role of the hurricane in the energy and heat balance of the atmosphere is to transport tremendous quantities of heat from near the bottom of the atmosphere, where incoming sunshine is most effective in producing warming, to high levels. Air converges from several directions toward a particularly numerous group of squalls and thunderstorms (each thunderstorm is a temporary, vertically rising column which must be fed by horizontal inflow). The squalls and thunderstorms grow into a more organized, single storm. Once established, the hurricane will continue as long as its environs consist of inflowing air with sufficient moisture and sufficient vertical instability. In its tropical stage the hurricane derives its energy from the release of latent heat of condensation produced in the formation of heavy rain. This heat maintains the updrafts in the inner part of the storm. The winds of the hurricane, which may attain tremendous force, are the resulting balance between the force of the updraft, the lowered pressure at the center of the

storm, and the deflective effect which forces the outer air to move toward the low pressure center in a spiral instead of a straight line.

8. Hurricanes of the Western Hemisphere. - The principal regions for the genesis of hurricanes in the Western Hemisphere lie between 10° and 20° North latitude in the Eastern Atlantic (these are termed Cape Verde hurricanes), in the Carribean Sea, and off the southwest coast of Mexico in the Pacific. The Cape Verde storms pose the greatest threat to the New England-New York Region, the Carribean storms are a secondary threat, and the Pacific storms are of no concern. The hurricane season is from late June until mid-October, with the greatest threat to New England in August and September. The Cape Verde hurricanes move toward the west, with the general drift of the wind about them, for a number of days with a forward speed of about ten miles an hour. Occasionally, a Cape Verde hurricane may proceed straight to the coast of Texas. More commonly they recurve any time after reaching the mid-Atlantic, that is, they turn northward, then east of north. After recurvature the storm usually increases in forward speed, typically to 25 to 30 miles an hour, occasionally to 60 miles an hour. Hurricanes that affect New England most severely usually arrive from the south-southwest after recurvature east of Florida and after skirting the Middle Atlantic Coast.

9. The typical hurricane early in its life is a circular symmetrical vortex, only about 50 miles in diameter, with an eye five to eight miles in diameter. During a period of several days, the typical storm grows until menacing winds may extend 100 to 200 miles from the center. There is a corresponding growth in the diameter of the eye. Upon reaching more northerly latitudes after recurvature the hurricane becomes less symmetrical, the eye less well defined, and the maximum wind speed decreases. The storm, however, spreads out to a radius of several hundred miles in the forward half and somewhat less in the rear half. These changes accompany a change in the fundamental nature of the storm, a change in the source of energy from latent heat of condensation to interaction of cold air with warm air. Hurricanes affecting the New England-New York Region range in stage of modification from a little-modified symmetrical vortex to a fully modified storm. In the latter case they are no different from other extra-tropical cyclonic storms. The temperature of hurricanes affecting the United States is nearly always in the 70's (°F), except when the modification of the storm is well advanced and a colder air mass is drawn into the whirl, in which case temperatures in the 50's may be experienced to the rear of the storm.

10. Hurricane wind speed is classically regarded as 75 miles per hour or faster. During almost every hurricane season wind speeds of 100 m.p.h. or higher occur in the tropics in one or more storms.

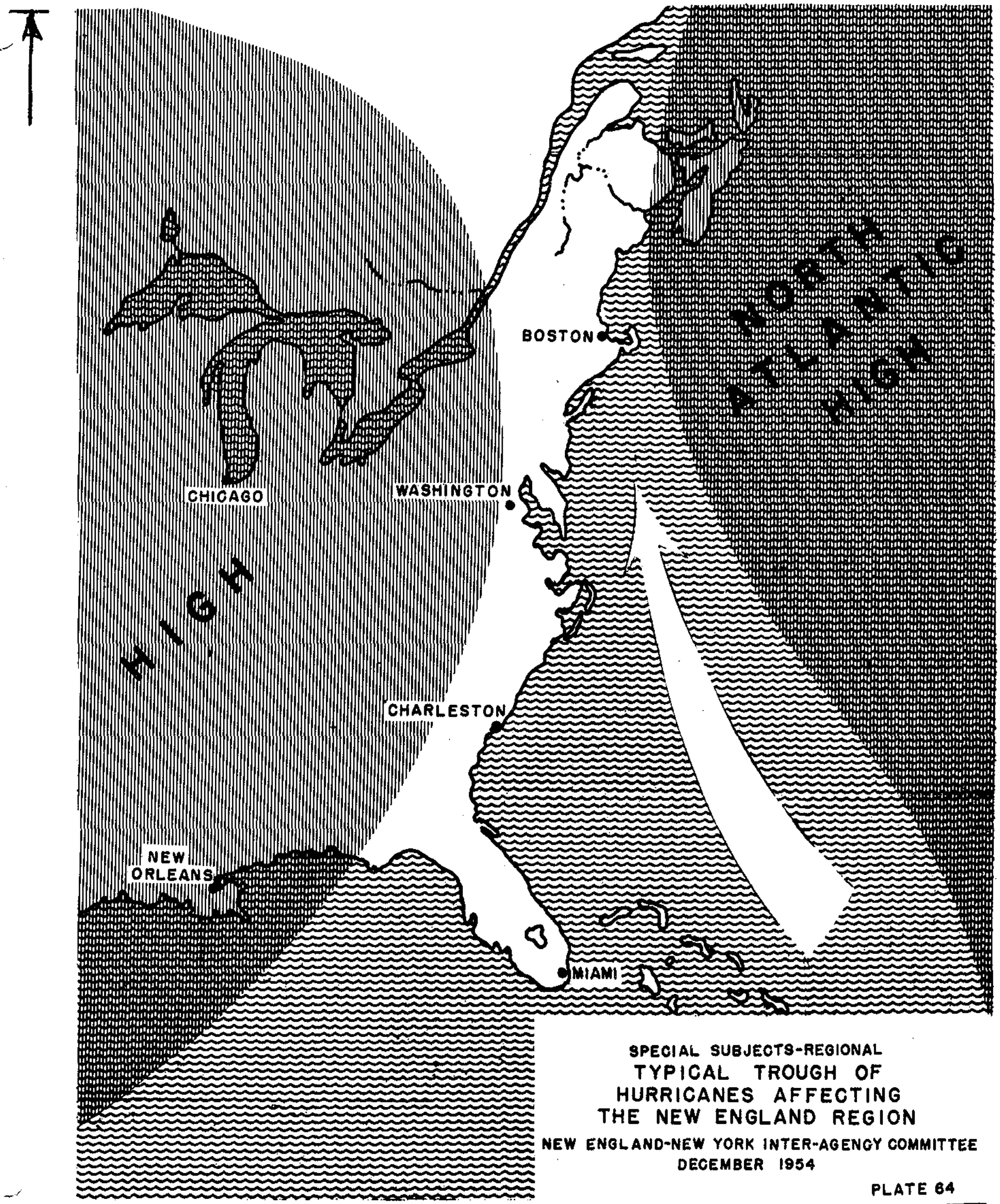
Upon reaching the latitude of New England, hurricane winds frequently weaken to maximum speeds on the order of 60 m.p.h., comparable to severe winter northeasters. Others weaken even more. This degeneration of storms from full-fledged hurricanes in the tropics to lesser intensities upon reaching New England makes difficult the specification of the frequency of hurricanes in New England. Occasionally a tropical cyclone maintains full hurricane force of 75 m.p.h. or more upon reaching New England. Storms of this type pose the greatest threat to man and his activities, though the lesser ones are by no means negligible along the coasts or in areas susceptible to river flooding.

11. Hurricane effects on large bodies of water. - The greatest hurricane disasters have resulted not from the wind but from the tidal flooding which occurs in susceptible shore areas as a result of the wind driven hurricane tide and the hurricane wave. The rise of water level at the shore may begin when the hurricane center is 500 miles away. This rise is caused by the wind-induced hurricane tide which is superimposed on the gravitational tide. Like the gravitational tide, the character and affect of the wind-induced tide varies with the contour of the coast and the sea-bottom. Hurricane tides are highest to the right of the point where the storm center passes inland and on concave shores may add three to ten feet to the level of the predicted gravitational tide.

12. As the center of the hurricane comes into the shore zone, a second and often more destructive phenomenon occurs. This is the sharply rising hurricane wave which in its extreme form may add as much as 20 feet to the level of the combined hurricane and gravitational tides. The forces involved in setting up this wave are not clearly understood. A small part of the increase in water level undoubtedly results from the very low atmospheric pressures associated with the center of the hurricane, but this accounts, at the most, for a rise of only four feet. Along the shores of the New England-New York Region, maximum rise in water level resulting from low atmospheric pressure would be less than three feet.

13. When the hurricane tide and wave combine with the gravitational high tide, severe tidal flooding occurs in susceptible shore areas. The southern coasts of New England and New York are particularly liable to this type of tidal flooding, and the associated wave, current and water damage.

14. Hurricane effects on land. - Exposed coasts are the greatest sufferers from hurricanes. Installations only a few feet above normal tide are often inundated. Erosion from waves and currents is often severe. Here, too, the winds are strongest, as they blow off the low-friction surface of the sea. Inland topographical irregularities and the general roughness of the ground impede the wind. However, wind damage may be both extensive and severe. Interference with transportation and communication, damage to trees and



SPECIAL SUBJECTS-REGIONAL

TYPICAL TROUGH OF HURRICANES AFFECTING THE NEW ENGLAND REGION

NEW ENGLAND-NEW YORK INTER-AGENCY COMMITTEE

DECEMBER 1954

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CHAPTER XXXIX

ARMY NED BOSTON, DEC. 1954

agricultural crops, damage to persons and dwellings from falling or flying objects and fallen wires, and the damage to small craft on interior lakes and ponds remain serious problems. Also, the torrential rains which commonly accompany hurricanes often intensify the damage caused by high winds.

15. A more critical threat posed by the heavy rainfall associated with hurricanes is the threat of interior flooding. Rains may be torrential long after the high winds have subsided especially if the forward movement of the storm decreases sharply or ceases. In the New England-New York Region the danger of a waning hurricane stalling is not great since the general atmospheric circulation is fairly vigorous much of the time. Flooding from hurricane rains is a threat in the region, however, particularly if the ground is saturated or streams are swollen from previous rains. Flooding as a result of rains in recent hurricanes has caused serious damage in the region.

HISTORY OF HURRICANES

16. The earliest hurricane on record in the New England-New York Region was that which occurred on August 15, 1635. Records indicate that numerous hurricanes have struck this region since 1635. In all probability others have occurred for which accounts are not available.

17. Twenty-four hurricanes are known to have caused damage in the New England-New York Region. The detailed accounts of the

twelve hurricanes that invaded or have passed close to this region since 1900 are most accurate and complete. These twelve storms had their inception in the tropics and retained average maximum winds of at least 50 m.p.h. (during a five minute period) when reaching the New England-New York Region. Several of these storms skirted the coast but were close enough to do damage to coastal property as well as shipping. With three hurricanes invading the New England-New York Region, 1954 undoubtedly ranks as the most destructuve year on the hurricane record for the region. The twenty-four storms are briefly discussed in the following paragraphs.

a. <u>1635 - August 15.</u> - Northeast winds of five to six hours duration, accompanied by torrential rainfall and high tides, caused widespread damage to trees and houses, devastated corn and hay crops, and wrecked many ships at sea and at moorings. Maximum high tide elevations of 20 feet occurred at Boston. Of the large number who lost their lives, many were Indians who were drowned when trapped by high water.

b. <u>1787 - September 19.</u> - High winds and tides from the storm passing close to the New England coast caused widespread damage to ships in and near port. Wind intensity is not known.

c. <u>1788 - August 19.</u> - Winds varying from south to west to northwest caused damage in Connecticut, Western Massachusetts, Vermont, and New Hampshire. All types of buildings, trees and crops were destroyed, and many lives were lost. The southern shore of Connecticut was subjected to the destructive effect of extremely high tides.

d. 1804 - September 9. - A severe storm reached the New England Coast causing damage to ships in and near port, especially the Port of Boston. Wind intensity not known.

e. 1815 - September 22-3. - In the "Great September Gale", winds ranging from east to southwest, as the storm progressed, caused general destruction in Long Island, New York, Connecticut, Rhode Island, and Massachusetts, and particularly along the coast of Connecticut, Rhode Island and southern Massachusetts. The wind caused extremely high tides, the maximum being that at Providence, Rhode Island, where the tide was seven and one half feet higher than the highest spring tides. About 500 buildings were destroyed, damages being estimated at $1,500,000. Elsewhere crops, forests, and property suffered heavily. Several hundred vessels were wrecked. Although some rain fell in Vermont and New Hampshire during the storm, it was light in other New England States.

f. 1821 - September 3-4. - Northeast and east winds caused much damage, the storm being extremely severe in New York, where the tide rose 13 feet in one hour. Little information is available on damages caused in New England; it is known that Connecticut suffered heavily.

g. <u>1829 - July 24</u>. - A tropical hurricane is reported to have reached Boston but little data are available on the extent of damage incurred.

h. <u>1854 - September 10</u>. - Damage in coastal areas of New England. The wind intensity and character of damage are not known.

i. <u>1869 - September 8</u>. - Southeast winds, accompanied by torrential rainfall, resulted in widespread destruction along the New England coast. Damage to vessels, buildings, and property was extensive. Provincetown was outside the 60-mile wide path of the storm, but at Providence, where the tide reached 6.2 feet above mean high water, damages were estimated at "hundreds of thousands of dollars."

j. <u>1878 - October 23-24</u>. - This storm caused heavy damage in the New England area, and in southeastern New York. Several vessels were sunk along the Connecticut coast, but little other detailed information is available.

k. <u>1879 - August 23-24</u>. - No information on the extent of damage is available for this storm which passed through New England. Since recording instruments were destroyed, information on wind velocities is not available.

l. <u>1893 - August 29</u>. - Although little detailed information is available, this storm is known to have caused severe damages in Connecticut and Rhode Island.

m. 1902 - September 16. - Winds were not of exceptional intensity as this storm passed through New England. However, it caused extensive damage to shipping and to crops and property in the Connecticut River Valley. Maximum sustained wind intensity at New York City was 65 m.p.h.

n. 1904 - September 16. - This storm resulted in the loss of many lives, destroyed numerous vessels, and caused considerable damage to seaside property in Long Island and New England. Sustained wind intensity of 84 m.p.h. was recorded at Block Island, Rhode Island.

o. 1920 - October 1. - Eastern New York, Connecticut and Vermont suffered damage from this storm which had a recorded maximum sustained wind intensity of 55 m.p.h. at New York City. Severe flooding was experienced in Northern Vermont with considerable damage in the Winooski River Basin. Extensive flooding also occurred in Southern New England.

p. 1924 - August 26. - Severe damage resulted from this storm along the Massachusetts and Rhode Island coasts. Ships and coastal property suffered heavily from high winds tides. Maximum sustained wind intensity at Block Island, Rhode Island was 78 m.p.h.

q. 1934 - September 9. - This storm, with recorded sustained wind speeds of 65 m.p.h. at New York City, affected Long Island, Connecticut and Rhode Island. Flooding in the Connecticut River caused considerable damage near Hartford, Connecticut.

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r. 1936 - September 19. - As a result of this storm which passed off shore some damage to shipping occurred along the Rhode Island coast. Sustained wind intensity of 58 m.p.h. was recorded at Block Island, Rhode Island.

s. 1938 - September 21. - This very destructive storm brought heavy damage to Long Island, Eastern Connecticut, Rhode Island, Massachusetts, Southwest New Hampshire and Northern Vermont. Sustained wind intensity at Providence, Rhode Island was 87 m.p.h. with gusts up to 150 m.p.h. High tides, high winds and flooding caused severe damage and loss of life in southern New England and Long Island.

t. 1940 - September 2. - Minor damage to shipping resulted from this storm which passed about 75 miles east of Nantucket, where it produced sustained wind intensities of 57 miles per hour.

u. 1944 - September 14-15. - This storm, which brought sustained wind intensities of 82 m.p.h. at Block Island, and gusts in excess of 90 m.p.h. caused property damage in Long Island, Eastern Connecticut, Rhode Island, and Eastern Massachusetts. Shore properties and beaches were the most seriously affected and many lives were lost.

v. 1954 - August 31. - Hurricane Carol swept across Long Island, through eastern Connecticut, Rhode Island, eastern Massachusetts, eastern New Hampshire and western Maine. Maximum sustained wind intensity was 80 m.p.h. at Block Island, Rhode Island, Rhode Island, with a recorded peak gust of 135 m.p.h. Coastal property and beaches were damaged severely along the coasts of Long Island and southern New England from a combination of high winds and excessive tides. Many lives were lost. Wind and rain damage was extensive throughout the Southern New England States.

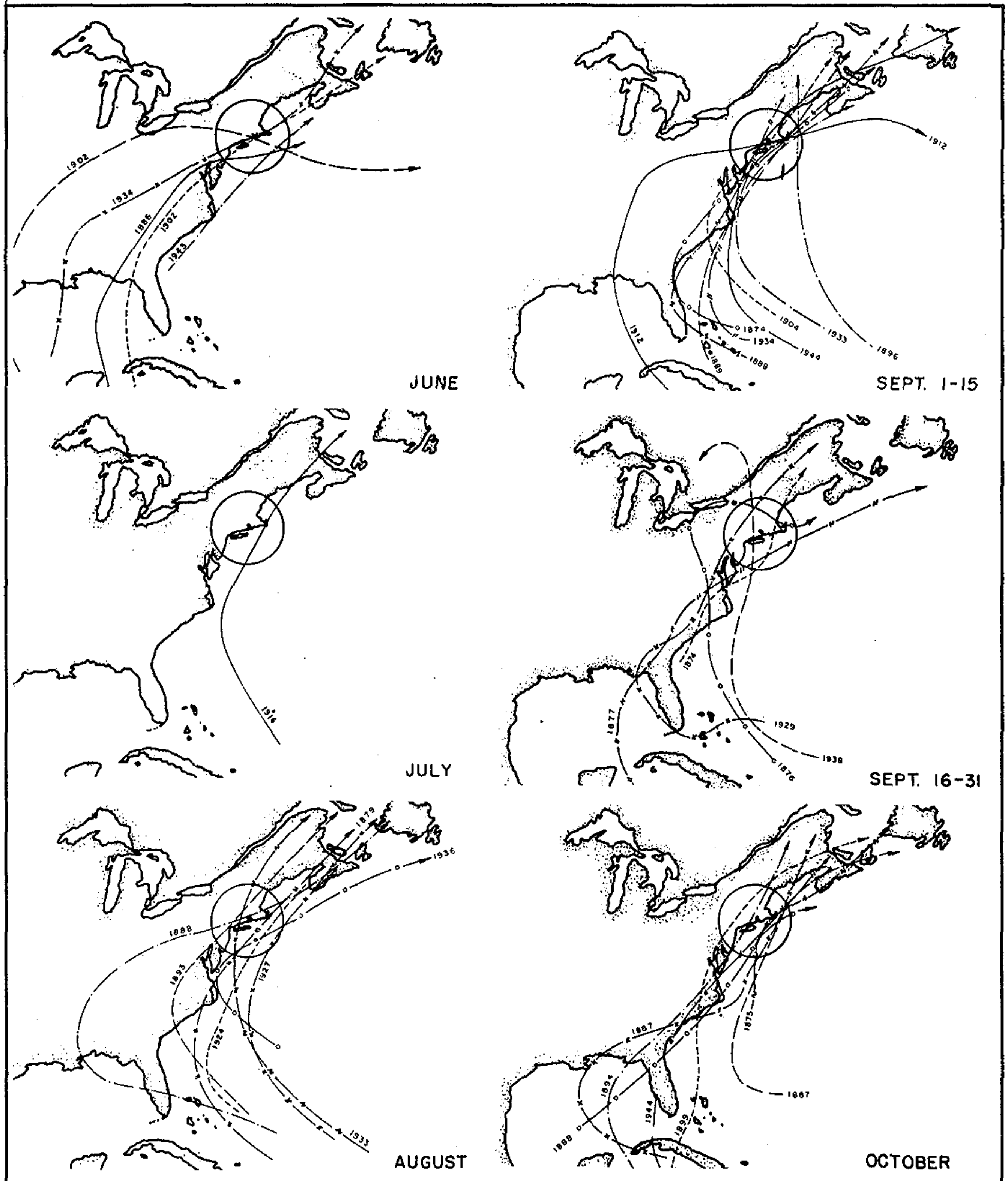
w. 1954 - September 11. - Hurricane Edna moved along the coast of New England damaging property in Eastern Massachusetts, Rhode Island, Eastern New Hampshire and Maine. The heavy rains which accompanied this storm, fell on saturated ground and caused interior flooding especially in Maine. Maximum sustained wind intensity at Block Island, Rhode Island was 70 m.p.h. with a recorded peak gust of 110 m.p.h.

x. 1954 - October 15. - Hurricane Hazel moved directly through western New York State bringing sustained winds of 72 m.p.h. at Binghampton, New York, and a recorded peak gust of 75 m.p.h. at Syracuse. The effects of wind and rain disrupted utility services and caused property damage throughout the western part of New England-New York Region.

18. Of the twenty-four storms discussed above, one occurred in the 17th century, two in the 18th, nine in the 19th and 12 in the 20th century. Of these, six occurred in August, 14 in September, three in October, and one in July. Aside from their concentration in the months of August, September, and October, there appears to be no regular pattern of occurrence. It can be observed that there are periods of concentration. Four storms have been recorded for the 26 year period from 1804 through 1829, three for the 25 year period 1854 through 1878, three for the 12 year period 1893 through 1904, and nine for the 31 year period from 1924 through 1954. Serious storms

have occurred at relatively short intervals. Storms in successive years have been recorded for 1787 and 1788, for 1878 and 1879, and for 1903 and 1904. Three storms were recorded in successive months in 1954. In spite of such interesting parallels there appears to be no general pattern of occurrence.

19. The most damaging storms which have struck the New England-New York Region as far as can be determined from the existing records appear to be those of August 1788, September 1815, September 1869, September 1938 and Hurricane Carol, 1954. There is some evidence that the storm of 1815 known as the "Great September Gale" may have been equal in magnitude to the Hurricane of 1938 and to Hurricane Carol. In general, however, information on the early hurricanes is too meager to invite reliable comparisons. It is apparent that in most instances, the intense winds of these storms have been accompanied by torrential rains and extreme tides, and that these have combined to produce increasingly severe damages as the region has become more highly developed. The tracks of some of these hurricanes and others are shown on Plate 65.



SPECIAL SUBJECTS-REGIONAL

PATHS OF TROPICAL STORMS OF HURRICANE INTENSITY

NEW ENGLAND-NEW YORK INTER-AGENCY COMMITTEE
DECEMBER 1954

PLATE 65
CHAPTER XXXIX

ARMY NED BOSTON DECEMBER 1954

20. General. - A most destructive hurricane arrived in the New England-New York Region on 21 September 1938. It cut directly across Long Island reaching the shore of Connecticut, near New Haven, in the mid-afternoon of the same day. It continued northward following the general line of the Connecticut River Valley. Tropical storms of the intensity of this storm have been uncommon in this area, generally swinging off into the north Atlantic. The lack of recent hurricane experience resulted in its striking without adequate warning. The devastation in the coastal areas was increased by the synchronization of the hurricane tide with the normal gravitational high tide. Further, with the late afternoon arrival of the highest tide, darkness set in to add to the confusion of those persons fleeing for their lives. Fortunately, the summer vacation season had ended and the majority of the people with shore cottages had returned to their permanent homes. However, at inland points along the rivers heavy antecedent rainfall had saturated the ground and filled the rivers to capacity. The additional rain accompanying the hurricane forced the rivers to overflow their banks, with consequent damaging flood conditions.

21. Antecedent conditions. - Immediately prior to the arrival of the September 1938 hurricane, the New England area had been subjected to a period of abnormal precipitation. Between the 12th and 16th of September, up to four inches of rain had fallen, saturating the ground in most of the New England States. There was comparatively

little surface run-off from these rains and the ground became thoroughly saturated. On 17 September, precipitation, starting with light showers and increasing in intensity, continued until 21 September when the heavy hurricane rainfall occurred. The total precipitation during this latter priod including six inches on the 21st, averaged nearly 12 inches over an area of 10,000 square miles, with an average of slightly over 16 inches falling over Connecticut and central Massachusetts. The antecedent precipitation had filled the brooks and streams to capacity, so that the rains accompanying the main storm were more than enough to cause the rivers to overflow their banks and flood the low areas.

22. <u>The Hurricane</u>. - The meteorological conditions existing on September 21, 1938 were just right to "invite" the hurricane to New England. A trough of low pressure, extending from North Carolina into central New England lay between a high pressure area over Newfoundland and another to the west over the eastern Great Plains. The hurricane, originating like most similar distrubances in the lower latitudes, had followed a general northerly course at a modest speed. It had been recognized as a fully developed hurricane by 18 September, and radio advisories were issued to all vessels at sea. On the morning of 21 September it was centered off Cape Hatteras, after which its forward speed increased. Instead of veering off to the northeast over the Atlantic Ocean, it continued northward up the trough of low pressure which was the path of least resistance, reaching

the region in mid-afternoon. Its speed of approach was probably over 80 miles an hour. The accompanying winds varied from 75 m.p.h. near sea level to over 120 m.p.h. at higher elevations (for five-minute durations), with gusts in excess of 150 m.p.h. at several locations.

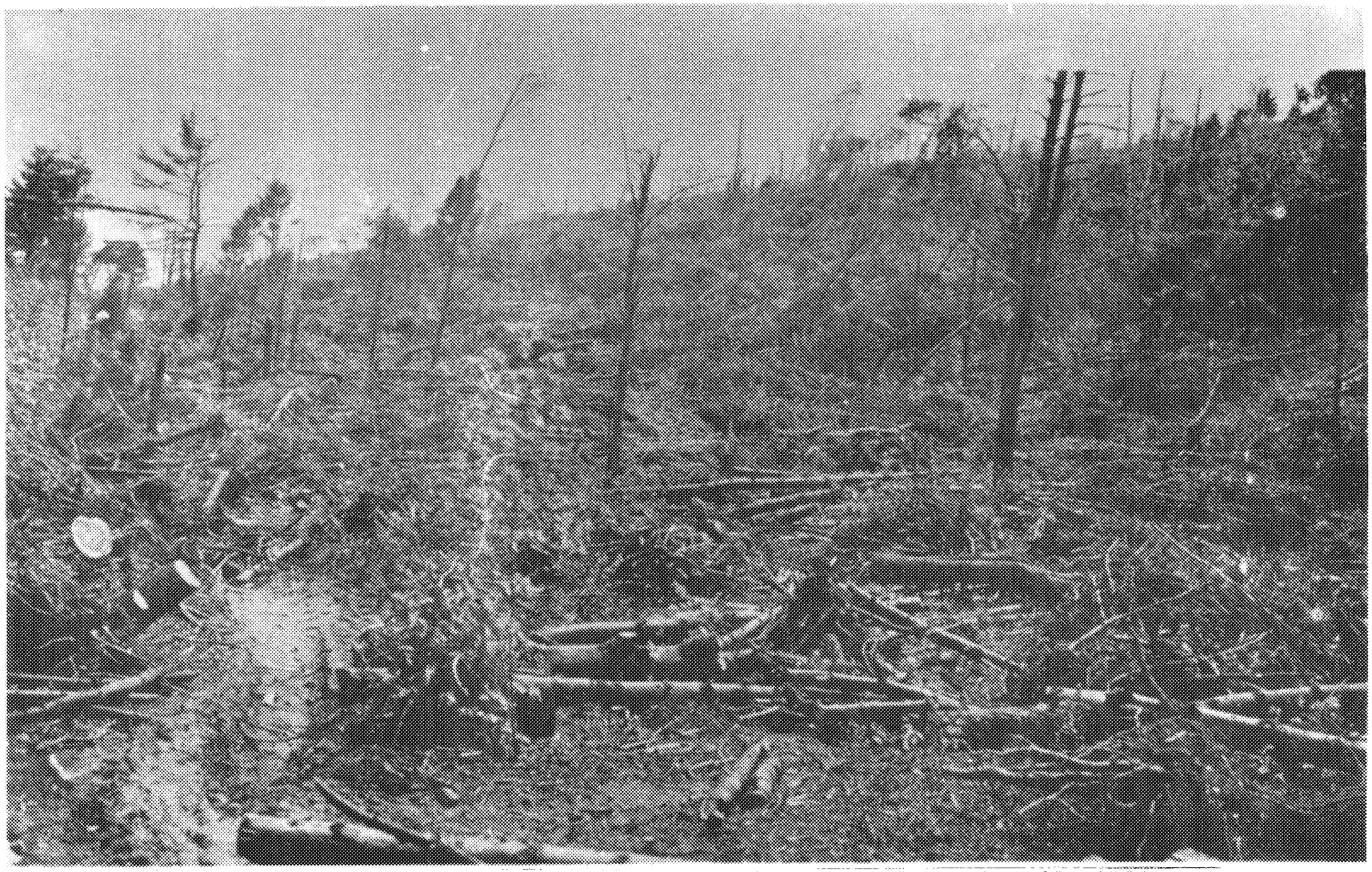
23. Damages. - The damages inflicted by the hurricane of 1938 were the heaviest that New England and Long Island had experienced from this type of storm. Along the coast, the losses were principally from tidal flooding and wind, whereas the inland sections suffered from river flooding and wind damage. Classes of damage are described in the following subparagraphs.

a. Loss of life. - As a result of this disastrous hurricane, more than 500 persons lost their lives. Over 200 of these were in Rhode Island alone, where in addition to very strong winds, tidal flooding was extensive and severe. The winds arriving in mid-afternoon damaged many trees and homes and disrupted the power systems. This situation, plus the fact that the hurricane tide arrived in the premature darkness hindered evacuation activities in the coastal areas.

b. Public. - Damage to public works and property was widespread. Buildings, parks, and roads located near the shore were destroyed or flooded by the force of the wind driven waves and high tide. Transportation came to a virtual standstill when bridges were swept away, highways washed out, flooded, or made impassible by falling trees and power lines. Many movable bridges were inoperative due to the flooding of their operating mechanisms. Damage to railroads, from washouts, lost bridges, damaged operating equipment, and rolling stock was also high. Communication and power facilities were seriously disrupted, when underground conduits were flooded and overhead wires were tangled amidst fallen trees and poles.

c. Private. - The principal destruction to private property occurred along the coast from tidal flooding, although at many locations along the inland rivers whole towns were inundated and houses swept away by flood waters. Numerous shore front communities were almost entirely wiped out by wind and wave. In the harbors and inlets thousands of small boats were lifted and dashed on the shore or smashed against the piers.

d. Commercial. - The losses to commercial establishments were severe. The city of Providence, Rhode Island, especially, was hard hit when the high tide and hurricane combined to flood a one and one-quarter square mile area of the business district. Cities and towns that were inundated by the over-flowing rivers also experienced serious commercial damages, but these were less extensive than in the coastal areas. Commercial fishing enterprises suffered a terrible blow to their business as whole fleets of fishing boats were demolished. No estimate is available of the total commercial damage incurred in the region. As an example of the seriousness of these damages Providence suffered direct losses estimated at



Timber damage. Near Keene, New Hampshire. Hurricane September 21, 1938.
New England-New York Region.

over $10,000,000, equivalent to about $24,000,000 at a 1954 price level.

e. Industrial. - No estimate of losses sustained by industrial concerns alone is available, although they were extremely high. In the coastal area, tidal flooding occurred on the ground floors at scores of plants and the consequent damage to machinery, equipment, and material amounted to many millions of dollars.

f. Utilities. - Public and private utilities were among the hardest hit. Generating equipment, power plants, distribution systems, and electrical equipment were put out of use, destroyed, or badly damaged. Their repair and restoration, especially in flooded areas, were slow, tedious, and costly. In the Providence area underground wiring was damaged by salt water and had to be replaced or repaired. Water supply systems suffered damages especially in Massachusetts; and sewerage systems were disrupted in southern New England.

g. Agriculture. - The majority of farm buildings were endangered by wind and those that were located in the low-lying areas near the overflowing rivers suffered flood damages as well. The greatest agricultural loss was to unharvested crops, and to the cropland. The large, onion growing section of the Connecticut Valley in western Massachusetts, and the rich tobacco land in Connecticut suffered heavily. Stacks of hay were strewn across the countryside. The nearly ripe fruit orchards were flattened and the fruit was destroyed. Thousands of vegetable gardens with late growing crops were damaged.

h. Military. - Army, Navy, and Coast Guard posts located near the coast sustained considerable damage. Buildings were demolished, piers and docking facilities badly battered, repair shops and equipment were flooded, and boats were grounded and crushed.

i. Harbors and shipping. - Damages to harbor protection works that were exposed to wave attack were heavy. In New England the cost of repair of breakwaters and jetties was estimated as close to $500,000. Seawalls and bulkheads were also extremely hard hit. Many docks and piers were reduced to a few sticks and pilings, much of the damage being caused by boats striking them. Lighthouses in exposed locations, although constructed to withstand exposure to heavy storms, suffered severely. Within the Long Island Sound area, alone, damages to lighthouse structures and supply depots was nearly $1,000,000. Boats of all descriptions, including tankers, freighters, passenger vessels, tugs, and barges, were damaged or destroyed, as many were driven ashore. New England fishing fleets, suffered heavily with nearly the entire Rhode Island and Connecticut fleets destroyed.

24. Summary. - The hurricane of 21 September 1938 was the most destructive storm, damagewise, to reach the New England-New York Region up to that time. Losses are reported to have totaled about one third of a billion dollars based on 1938 price levels, but no detailed figures are available to support this estimate. Over 500 lives were

Small craft damage. Barrington (above) and Wakefield, Rhode Island. Hurricane September 21, 1938. New England-New York Region.

lost. Devastation was widespread, with the major part of the damage being caused by tidal flooding and wind along the coastline. The "Supplemental Report on Hurricane of September 21, 1938" prepared by the U. S. Engineer Office, Providence, R.I. indicated damages from tidal flooding along the southern coast of New England totalling $55,000,000. Not considering the great building expansion and increase in economic activity that has taken place since that date, the damage would exceed $145,000,000 based on 1954 price levels. No comparable figures are available for wind damage.

25. The long period of antecedent precipitation and the extremely heavy rainfall accompanying the hurricane produced floods which are presently the historical floods of record at many localities. Major floods occurred in the Merrimack, Thames, Connecticut and Housatonic River Basins which resulted in damages estimated at over $70,000,000. Recurrence of floods of equal magnitude in those basins would cause damages estimated at $165,000,000 at a 1954 price level.

HURRICANE OF SEPTEMBER 14-15, 1944

26. The center of the Hurricane of 14-15 September 1944 after crossing the eastern end of Long Island reached New England shores at Westerly, Rhode Island. Fortunately it arrived on the ebb tide, so that the destruction associated with tidal flooding was not evidenced. Rainfall was heavy, with 4.5 inches falling in a six-hour period at Providence. The storm traveled in a northeastward

direction, leaving the New England area north of Plymouth, Massachusetts. The majority of the damage in southern New England and on Cape Cod was to shores and beaches, shore property, and some harbor installations. Water supply systems suffered minor damages in Massachusetts and Rhode Island. The maximum wind velocity (for a five-minute period) recorded at Block Island was 82 m.p.h. Extreme and gust wind velocities exceeded 90 m.p.h. at many locations in Connecticut, Rhode Island and Massachusetts. In the New England area, it was reported that 30 lives were lost, over 1,300 houses damaged or destroyed, and nearly 650 boats demolished or badly battered.

27. Hurricane Carol. - The center of Hurricane Carol crossed the south shore of Long Island slightly east of West Hampton about 8:30 A.M. (EST). An hour later, it passed into Long Island Sound off Cutchogue. By 10:30 A.M. (EST), it was over the southeast shore of Connecticut near the mouth of the Connecticut River. Curving slightly on a northward course, the center passed 5 to 10 miles west of Worcester, Massachusetts, about noon and penetrated into south-central New Hampshire about 1:30 P.M. (EST). In mid-afternoon, the strength of Carol's winds and its speed of forward progress diminished as the center traveled northward over the rugged terrain of New Hampshire. At 7:30 P.M. (EST), the center was located at latitude 46°N., longitude 71°W., just north of the Canadian border, and the weakening storm had lost all hurricane force.

28. In Long Island and New England the storm damage may be divided into three principal classes. The first, caused by wind alone, was most severe over the area east of the hurricane's center line of passage and south of the northern border of Massachusetts. This area included Long Island east of Riverhead; New London, Tolland and Windham Counties, in extreme eastern Connecticut; all of Rhode Island; and Massachusetts east of the Webster-Worcester-Fitchburg line out to the "elbow" of Cape Cod. The area was swept during the morning by sustained winds of hurricane force with gusts up to 125 m.p.h. Countless trees were toppled, blocking roads, smashing buildings and automobiles, and wrecking electric and telephone lines.

Roofs, chimneys, steeples, aerials, signs, windows, store fronts, radio and television broadcasting towers were damaged or destroyed. All forms of transportation were crippled. In this heavily-populated area, the ordinary activities of daily living were forcibly suspended by the storm. Hundreds of thousands of families had to do without telephone service and without electricity for cooking and lighting for days until utility workers were able to effect repairs. Streets and highways were quickly cleared of fallen trees, but not until a week had elapsed were utility services generally restored to normal. In addition, numerous factories (in Rhode Island especially) were so badly damaged that workers could not return to their jobs for periods ranging from several days to three weeks, with consequent heavy financial loss.

29. Similar but lesser devastation took place during the morning over central Long Island and the strip of Massachusetts and Connecticut extending from the path of the hurricane center to the Connecticut Valley. This district was lashed by 45 to 55 m.p.h. sustained winds, with gusts to 65 m.p.h., and by even higher winds close to the center of the storm. In the afternoon, winds of like force pummeled the southwestern corner of New Hampshire, the portion of the same state east of the path of the storm center and south of Lake Winnipesaukee, and southwestern and south-central Maine. Along the New Hampshire and Maine coasts east to the Kennebec River, winds were higher than over the rest of northern New England; sustained

Wind damage. Utility service and use of street disrupted by fallen trees. Hurricane Carol. Quincy, Massachusetts. New England-New York Region.

speeds were in the 60-70 m.p.h. class and gusts ranged to 80 m.p.h. Vermont, central and northern New Hampshire, most of Maine, and the western parts of Massachusetts and Connecticut experienced gale force winds, but no really severe velocities, and the same held true for eastern New York State including the western end of Long Island.

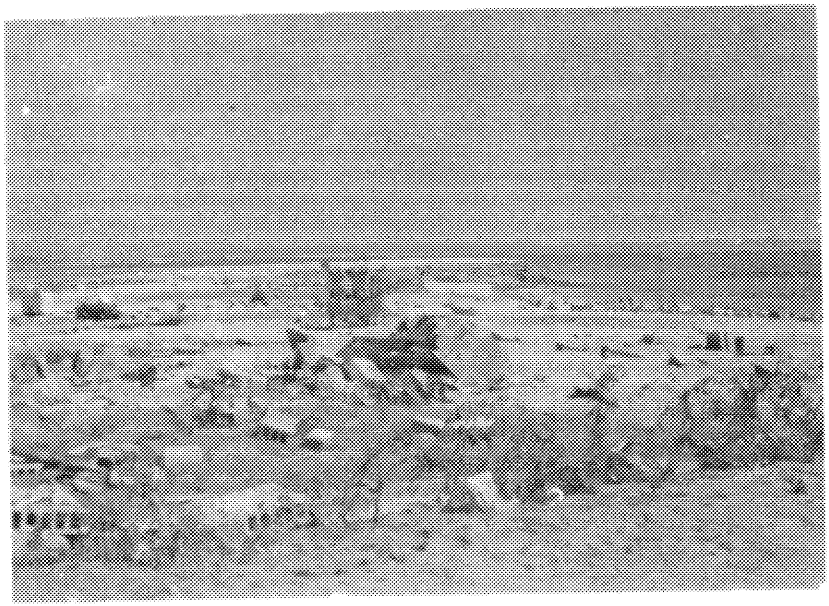
30. The second and most devastating type of storm damage was that inflicted on shore areas by tidal flooding. The hurricane struck Long Island and southern New England close to the time of gravitational high tide; this circumstance combined with the hurricane tide flooded harbors, beaches and similar low-lying areas and wrecked everything in the path of the water. Seaside resorts, thronged by thousands of vacationists, were thus areas of particularly heavy damage. Were it not for the prompt and efficient measures taken by local governmental, police and civilian defense agencies to evacuate people from beach cottages and hotels the loss of life would have been far greater. Wave damage extended during the afternoon to include the New Hampshire shore and much of the Maine coast.

31. The third type of damage was the havoc done to pleasure and fishing craft and shore structures by the combined action of wind and water. An estimated 4,000 small craft were thereby either seriously damaged or destroyed, as they were torn from their moorings, sunk, or pounded on the shore.

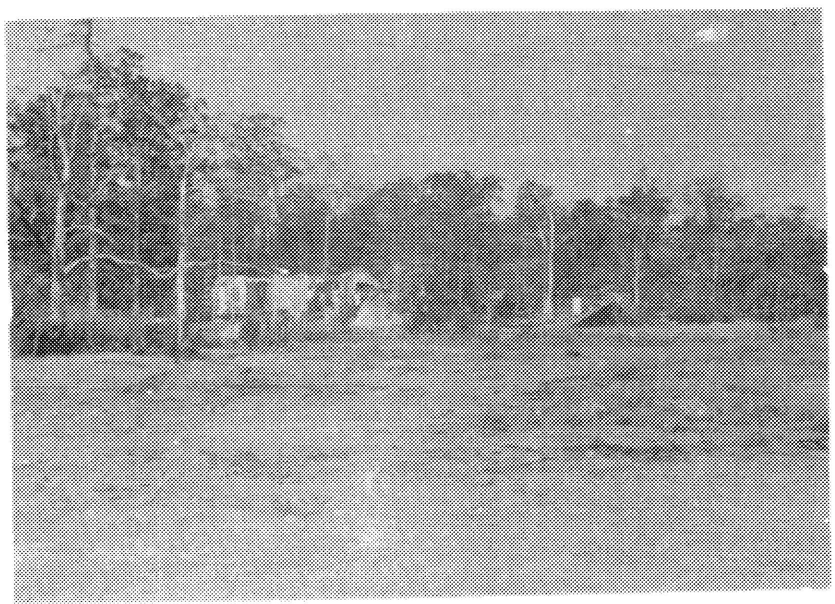
32. A summary of storm affects resulting from Hurricane Carol by states follows:

a. New York State. - The center of the hurricane traversed the eastern end of Long Island along the West Hampton-Cutchogue line during the hour between 8:30 and 9:30 A.M. (EST). Severe wind damage occurred from about the Sayville-Port Jefferson line all the way out to Montauk Point, and was at a maximum between the West Hampton-Riverhead-Cutchogue area and Montauk Point. From the Bayshore-Islip-Northport area westward, wind damage was less severe and was relatively small in and around New York City. Water and marine damage, however, was heavy all along the Sound on both the Long Island and Westchester shores. This type of damage was also high along the eastern and central portions of the southern coast of Long Island. Montauk Point was isolated by a severe washout east of Amagansett, and the 300-foot Mackay Radio tower there was blown down. In Port Jefferson harbor, on the north shore, over 40 small craft were damaged or destroyed. The 200-foot ferryboat "Orient" was driven ashore by the storm. Peak wind gusts reported during the hurricane at Long Island locations include: 54 m.p.h. at New York International Airport; 62 m.p.h. at La Guardia Field; 85 m.p.h. (rooftop level) and estimated 125 m.p.h. (410-foot level) at Brookhaven National Laboratory.

b. Connecticut. - Carol's center traversed the extreme eastern part of Connecticut between 10:30 and 11:30 A.M. (EST). Wind damage was relatively light in western Connecticut, but increased



Private property damage. East side of Charles Neck, Marion, Massachusetts. Hurricane Carol. New England-New York Region.



Private property damage. Cottages from Charles Neck, Marion, Massachusetts. New England-New York Region.

eastward from moderate to severe over the rest of the state. Water and marine damage was heavy along the entire coast, and greatest in the New London-Groton-Mystic section. In these towns, waters flooded not only the beach areas but the business and permanent residential districts as well. Notable also was water damage at Stonington, in the New Haven area, at Bridgeport and Stamford. New London, Middlesex and New Haven Counties were designated disaster areas. Peak gusts observed during the hurricane are the following: 60 m.p.h. at Bridgeport; 64 m.p.h. at Hartford; 65 m.p.h. at New Haven; and 80 m.p.h. at Windsor Locks.

c. Rhode Island. - Rhode Island was very hard hit, being in the zone of strongest winds as the hurricane passed northward through nearby Connecticut. Its southern coast and the numerous waterways associated with Narragansett Bay were scenes of enormous water and marine damage. The downtown section of Providence was flooded and Westerly was especially hard hit. Indeed, the worst of the hurricane's fury was concentrated on this State, all of which was declared a disaster area. A peak gust of 105 m.p.h. was recorded at the Providence Weather Bureau Airport Station; 130 m.p.h. at Block Island; and an estimated 125 m.p.h. at Quonset Point Naval Air Station.

d. Massachusetts. - The center of the hurricane traversed the state from about 11:30 A.M. to 12:30 P.M. (EST). Wind damage was light in the western third of the state, moderate to heavy in the central portion, and heavy throughout the entire eastern area, except relatively light on Martha's Vineyard, Nantucket and the outer part of Cape Cod. Water and marine damage were heavy all along the coast, with the maximum in Buzzard's Bay and along the southern side of the Cape eastward to Chatham. Population centers, such as Fall River, New Bedford, Brockton, Boston, Worcester, Lawrence and Lowell sustained major losses. In Boston, a noteworthy feature of the storm was the toppling of the steeple of historic Old North Church. The following counties were designated disaster areas: Suffolk, Essex, Middlesex, Norfolk, Plymouth, Bristol, Barnstable, Dukes and Nantucket. Peak gusts include: 100 m.p.h. at Blue Hill Observatory in Milton; 88 m.p.h. at Otis Air Force Base near Falmouth; 77 m.p.h. at Nantucket; 52 m.p.h. at Pittsfield; 93 m.p.h. at Salem U. S. Coast Guard Air Station; and 71 m.p.h. at Westover Air Force Base near Springfield.

e. New Hampshire. - The center of the hurricane pushed northward through New Hampshire during the afternoon. Since the storm's intensity was diminishing, central and northern New Hampshire sustained relatively light wind damage. This type of damage was moderate to heavy in the southern portion, and greatest in the southeast, where Strafford County was designated a disaster area. Water and marine damage was extensive along the coast, at such crowded beach and boating centers as Hampton, Portsmouth, Exeter, New Castle and Dover. In addition, approximately 150 small craft on Lake

Winnipesaukee were damaged or destroyed. The following peak gusts were experienced in New Hampshire: 63 m.p.h. at Concord; 65 m.p.h. at Laconia; 41 m.p.h. at Lebanon; and 52 m.p.h. at Grenier Air Force Base near Manchester.

f. Maine. - Maine, on the dangerous side of the storm, sustained heavy wind, water and marine losses. Most of the damage was suffered in the southwest and south-central portions, and along the coast eastward to Bath. The northeastern coast and the northern interior was out of range of the severe part of the storm. York, Cumberland, Sagadahoc, Lincoln, Knox and Waldo Counties were designated disaster areas. Portland, Brunswick, Auburn-Lewiston and Augusta were hard hit. Peak gusts include: 73 m.p.h. at Dow Air Force Base near Bangor; 78 m.p.h. at Portland; 84 m.p.h. at Brunswick Naval Air Station; estimated 40 m.p.h. at Greenville; 48 m.p.h. at Houlton; and 50 m.p.h. at Old Town.

g. Vermont. - Vermont was on the western side of the weakening hurricane as it travelled northward through New Hampshire, and thus had the least damage of any part of New England. Heaviest property and utility damage was experienced in Brattleboro and adjacent areas in the southeast. Montpelier's peak gust was 35 m.p.h., Newport's was 25 m.p.h., Burlington's 50 m.p.h.

33. Hurricane Edna. - Hurricane Edna, the second such storm to visit the east coast within 11 days, struck Long Island and New England another blow on September 11, 1954. Smashing into Martha's

Vineyard shortly after 1 P.M., it crossed Cape Cod Bay, following a slightly curving northeasterly course off shore; it headed toward extreme eastern Maine and passed close by Eastport, Me., into New Brunswick shortly after 7:30 P.M. Thus, nearly all of Long Island and New England, except Cape Cod and the islands to the south, were on the west or north side of the storm, and were spared the full brunt of the wind force. Highest gust velocities in these areas came with the storm's back-lash and reached to above 90 m.p.h. Gusts above 100 m.p.h. were recorded on Martha's Vineyard and outer Cape Cod.

34. Major damage was produced by the very intense rainfall preceding and attending the storm's onslaught. The rainfall was of excessive and near-record intensity for a number of hours and amounts of 4 to 8 inches were general along coastal areas, southeastern New England, and eastern Maine. Local floods and washouts were widespread. Southern and eastern Maine areas were especially hard hit, with drownings; highway and railroad right-of-ways honeycombed with treacherous washouts; many trees felled, taking electric and telephone lines down with them, and substantial losses to grain crops in Aroostook County. Major losses in other parts of the affected areas were of a similar nature - road washouts, serious floods, and electric and telephone lines downed by felled trees.

Wind damage. Trees and utility poles block street. Hurricane Edna. Castine, Maine.
New England-New York Region.

35. Hurricane Hazel. - The center of Hurricane Hazel moved northward through central Pennsylvania, and entered the western portion of the region in New York State south of Lake Ontario at about 8:30 P.M. The storm produced recorded gust winds of 75 m.p.h. at about 10 o'clock in Syracuse, lying to the east of the center, and of 73 m.p.h. at about 11:30 P.M. in Buffalo, to the west of the center. Maximum wind velocities of 90 m.p.h. were experienced in the Finger Lakes area. It brought wind gusts up to 79 m.p.h. as far east as western Long Island and produced damaging waves in that area. Unlike Hurricanes Carol and Edna, rainfall accompanying Hurricane Hazel was relatively light in the region, except in the extreme western portion. Jamestown, New York, which lies a few miles outside the extreme southwestern portion of the region, had 5 inches of rainfall during a twenty-four hour period ending 7 A.M. on the 16th of October, and over 1 1/2" of rain fell in the vicinity of Buffalo and Niagara Falls. Rainfall was very light or absent in the Finger Lakes portion of the region.

36. Because of the moderate to small amounts of rainfall throughout much of the region during the storm, flood damage was not widespread. Serious damage from flooding was reported only in Chautauqua County, the westernmost county in the region. Minor damage was caused by the overloading of local drainage facilities in Buffalo and Niagara Falls, New York. The principal damage in the latter areas and the only damage at other points in the New York State portion of the Region were caused by high winds. Trees

and large branches were blown down carrying utility wires with them. Falling trees also damaged buildings and blocked highways. There was extensive damage to TV aerials, and some roofs were damaged. Small boats were damaged by wind and wave in western Long Island waters.

37. The principal damages were suffered by residential and commercial properties, and by utility services. Utility customers were affected for varying periods by loss of utility service. Full service was restored throughout the region in about three days; however, many of the repairs were of a temporary nature. The most serious damages to both utility services and to residential and commercial property resulting from Hurricane Hazel were suffered in an area in west central New York, centered on Syracuse.

37a. The major damage areas in New England are shown on Plate 66. The major damage areas for Long Island, New York and vicinity are shown on Plates 67 and 68.

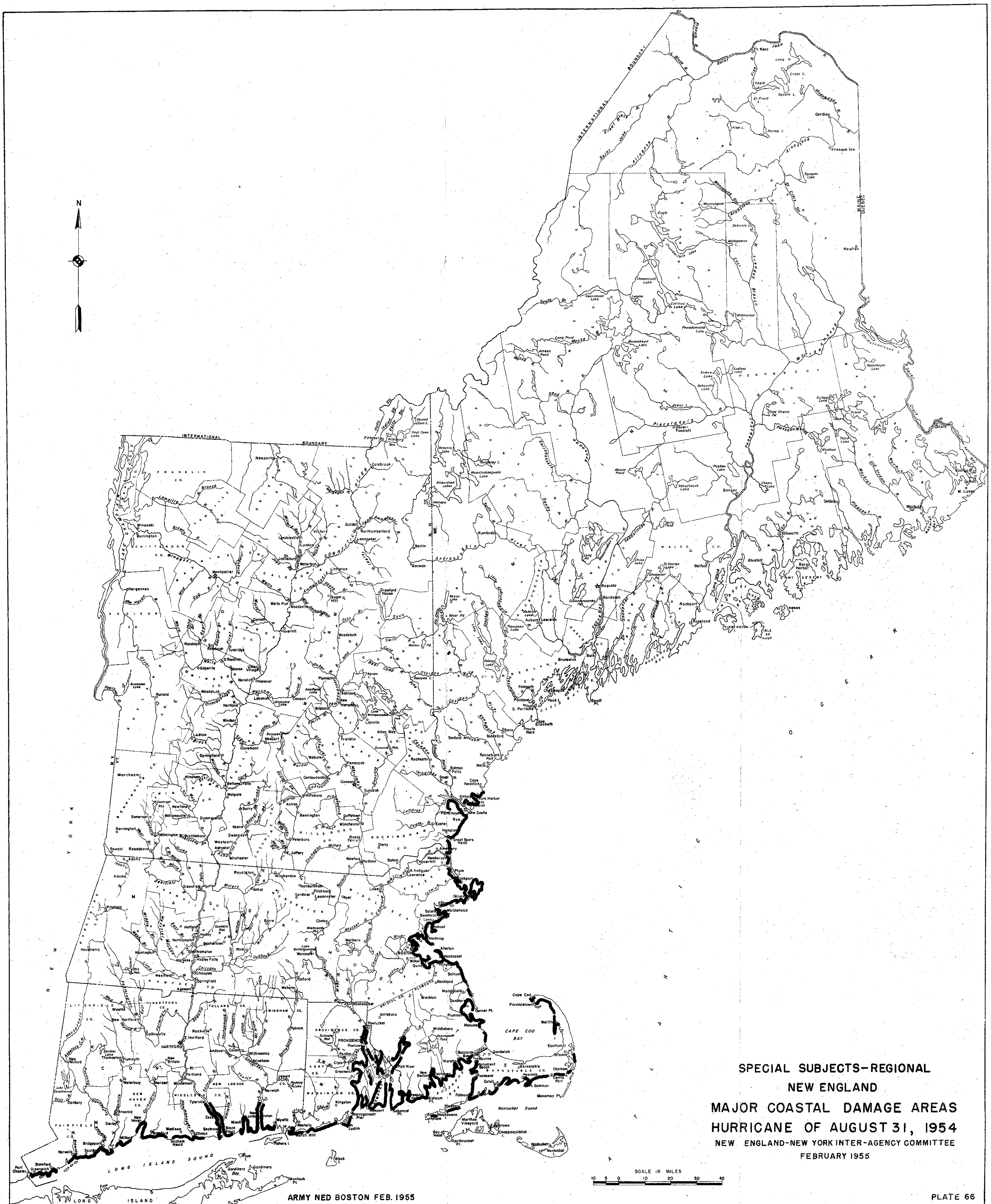
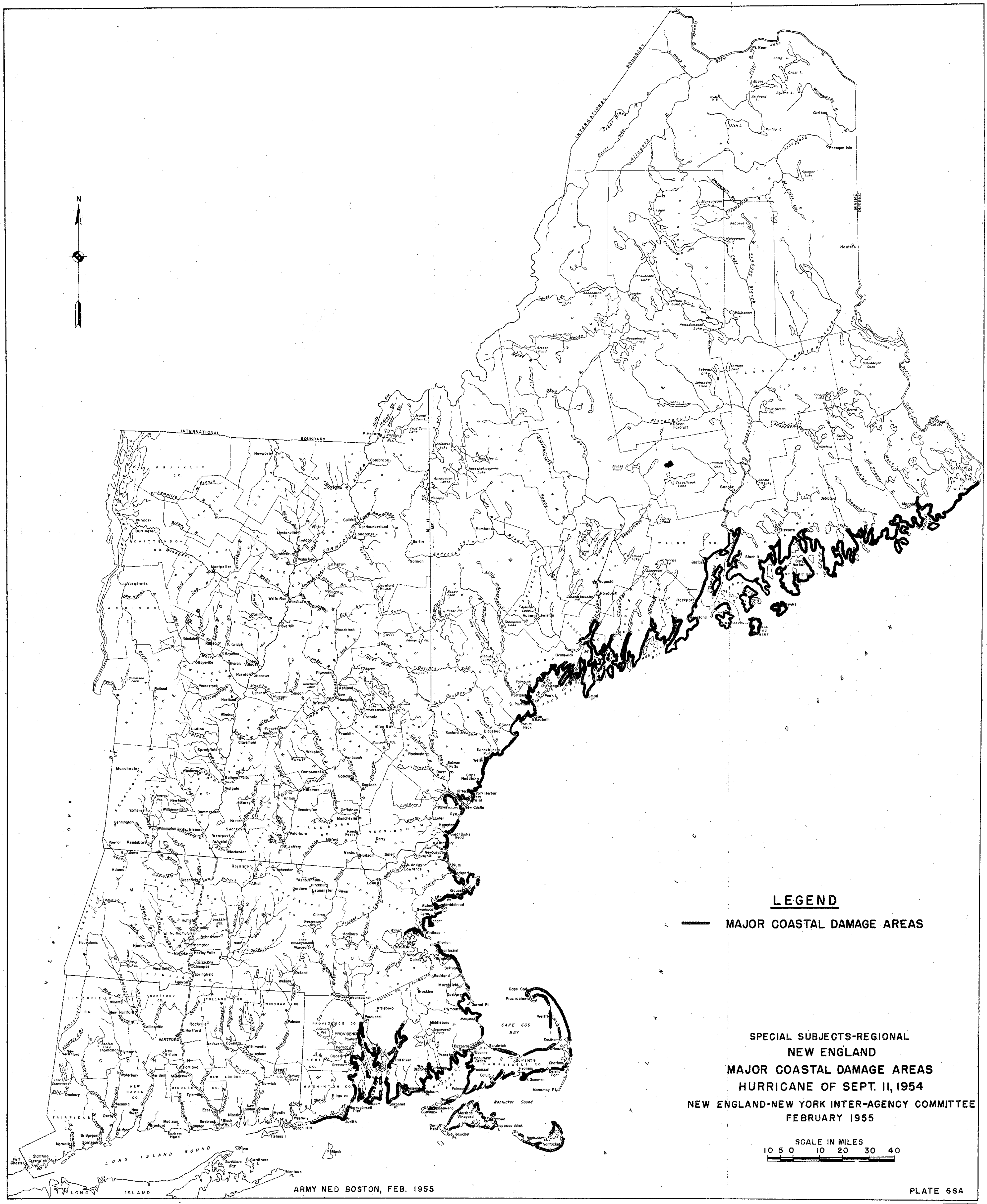
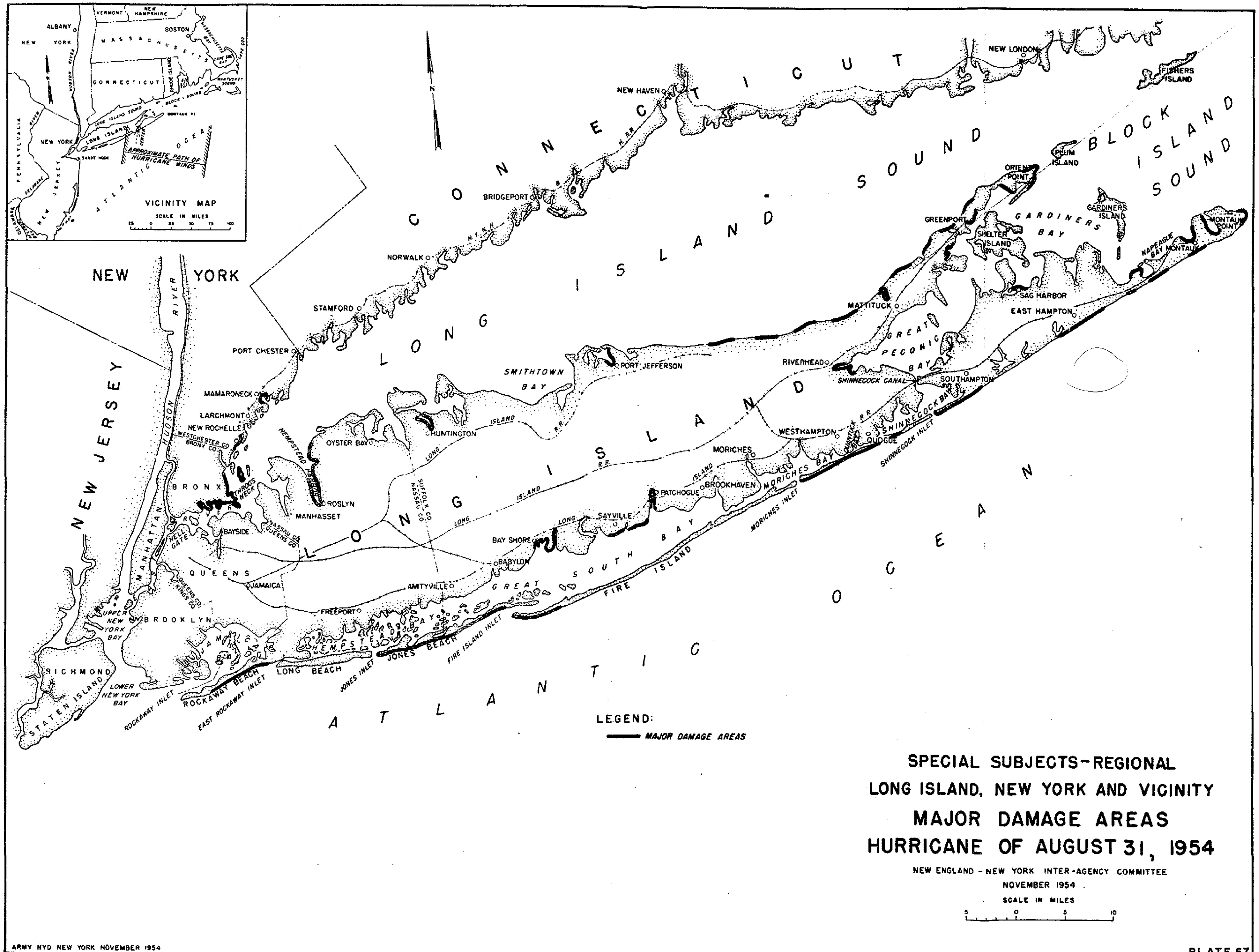


PLATE 66

CHAPTER XXXIX



CHAPTER XXXIX



SPECIAL SUBJECTS-REGIONAL
LONG ISLAND, NEW YORK AND VICINITY

MAJOR DAMAGE AREAS
HURRICANE OF AUGUST 31, 1954

NEW ENGLAND - NEW YORK INTER-AGENCY COMMITTEE
NOVEMBER 1954

SCALE IN MILES
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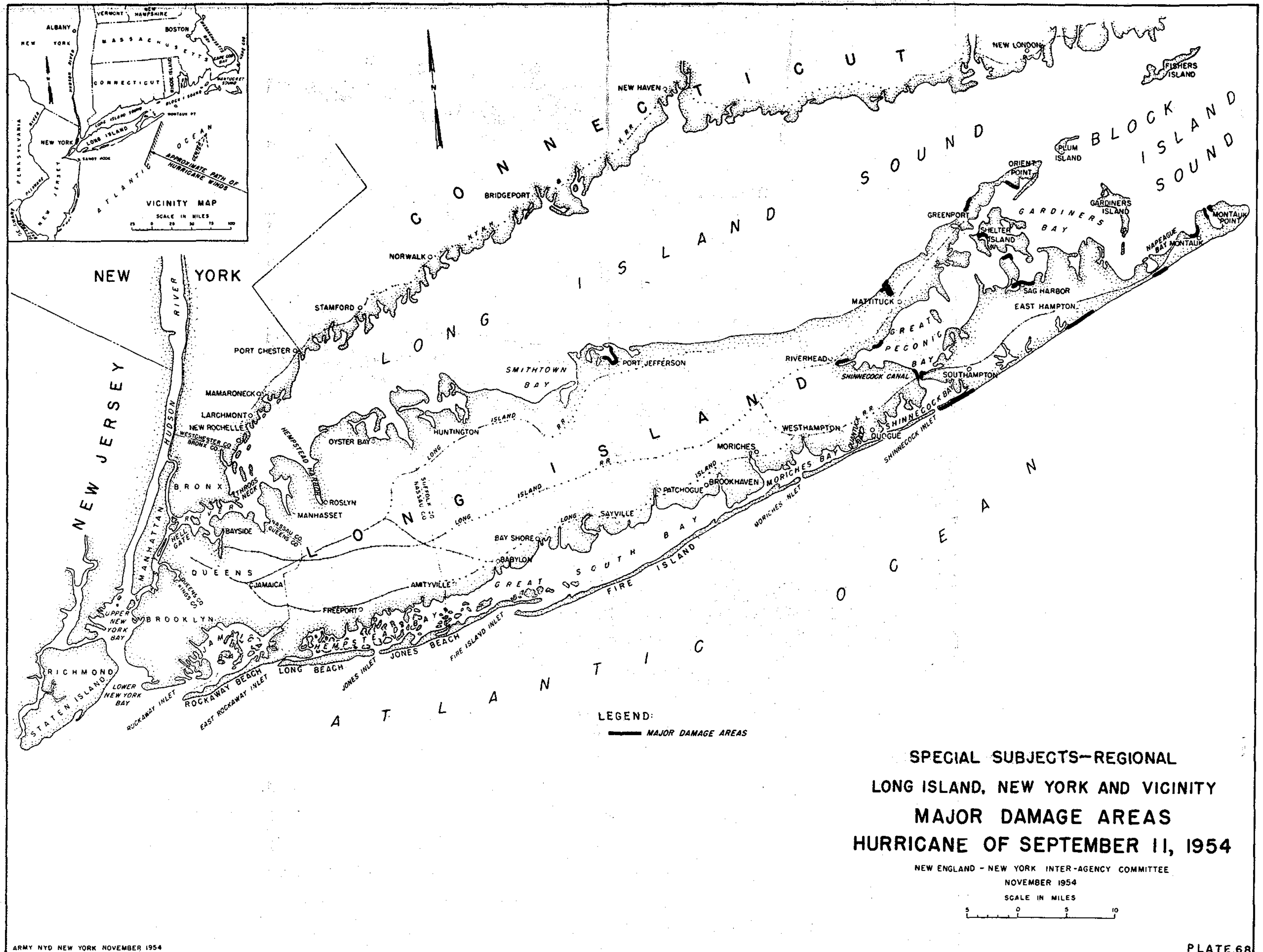


PLATE 68
CHAPTER XXXIX

DAMAGES CAUSED BY 1954 HURRICANES

38. <u>General</u>. - In general, damage figures presented in this section are limited to estimates of damage sustained in coastal cities and towns, except those resulting from Hurricane Hazel. All estimates are based on information obtained from Federal, State, City and Town officials; from responsible officials in industrial and commercial enterprises; and from trained damage survey personnel specially assigned to investigation.

39. Time and personnel limitations precluded detailed coverage of each community affected by the 1954 hurricanes, however, all communities having tidewater frontage were inspected. Available estimates of damages sustained in inland communities from hurricane winds and rains are included.

40. Unless otherwise noted, all damage figures for New England include both direct damages to structures and equipment, and indirect damages such as loss of revenue and wages. Damage figures for areas in New York State do not include loss of revenue and wages. Where applicable, separate, estimates are indicated for damages attributable to each of the three hurricanes. In general, estimates are given by States, but detailed estimates have been provided for such critical damage zones as Fairfield and New London, Connecticut; Newport, Bristol, and Providence, Rhode Island; and Assonet and New Bedford, Massachusetts.

41. <u>Loss of life</u>. - Records of the five hurricanes that have struck the New England-New York Region during the past 16 years indicate that the greatest danger to life has been from water rather than from wind alone. The heaviest tolls have unquestionably occurred as a result of tidal flooding although exact figures are not available. The most significant factors determining the degree of danger appear to be the adequacy of warning services, the relative timing of gravitational and hurricane tides, and the season of the year and time of day the hurricane occurs. Of these, there seems little doubt that the adequacy of the warning system, is the most important single factor. Improved forecasting techniques and warning devices, as well as the general awareness of danger among coastal residents were the major factors in the relatively small loss of life experienced in the 1954 hurricanes as compared with the 1938 hurricane.

42. Hurricane Carol (August 31, 1954), although occurring at the height of the summer recreational season, found both coastal and inland residents more fully aware of hurricane danger than was the case in 1938. Forecasting techniques, warnings and evacuation helped to protect affected populations. In addition, the hurricane struck in the morning in full daylight, aiding the orderly evacuation of dangerous coastal areas. Consequently, in spite of extreme tidal flooding, the loss of life was surprisingly low. The center of Hurricane Edna, which struck the region 11 days later, passed over

Rescue operation. Tidal flooding. Hurricane Carol. Westport Point, Massachusetts. New England-New York Region.

the eastern end of Cape Cod. This storm was well forecasted and widely publicized. As it came at a time of relatively low gravitational tide and affected a smaller area, it was not accompanied by serious tidal flooding. The loss of life was much less than in Hurricane Carol.

43. **Total lives lost** in New England in both Hurricane Carol and Hurricane Edna has been reported by the American Red Cross to have been 58, with 27 deaths in Massachusetts, 21 in Rhode Island, eight in Maine, and one each in Connecticut and New Hampshire. Three lives were lost in Long Island. No exact information is available on the number of deaths assignable to various contributory causes. It is known, however, that the vast majority were by drowning, occurring either as boat owners attempted to save their craft, as people fled to safety from the coast, or as a result of the flooding of interior rivers. Other fatalities were caused by falling trees, flying debris and by over-exertion. It is reported that Hurricane Hazel contributed to the deaths of two persons in New England and between 14 and 19 persons in New York State.

44. Public property. - The damages sustained by various public properties in severe hurricanes such as the three affecting the region in 1954, particularly to trees, highways, and coastal structures, are comparable in monetary terms to the widespread damages to private, commercial, and industrial property. In general, although some damage was sustained by public buildings such as schools, halls,

libraries, water and sewage works, and by such installations as military bases, the bulk of hurricane damages to public property was that occurring to highways and bridges, public parks and forests, and to publicly-owned beaches, shore recreational structures, shore protective structures and navigational improvements. Damages to various types of public properties are described in the following paragraphs. Detailed damages to public works in New England are shown in Table 85.

45. Public buildings. - Damage to public buildings was not particularly serious or extensive in comparison to damage to other public property. In inland areas, primary damage was due to wind effect on roofs and windows with secondary damage due to rain entering openings made by wind action. Damage was more extensive in coastal locations. In some instances public buildings were affected by tidal flooding such as the City Hall and post office at Providence, Rhode Island, and a fire station at New London, Connecticut. Bathhouses were destroyed at Osprey Beach and Shenecosset Beach in Connecticut, and Napatree Beach in Rhode Island. At Nahant, Massachusetts, a recently constructed school gymnasium collapsed.

46. Highways. - In many inland towns and municipalities which did not suffer flooding, the principal loss in 1954 hurricanes appeared to be the cost of clearing fallen trees and debris from public streets and from other publicly-owned property, and of restoring roads washed out by the accompanying rains. In coastal areas, many roads

and beach parking areas were covered with sand, debris, or both; others were washed out, undermined, or endangered by damages to protecting revetments or walls. Typical of such damages were: those suffered between Westhampton and Montauk Point on the south shore of Long Island, roads were inundated and buried under sand; at Hammonasset Beach, Connecticut, 18 inches of sand covered the parking areas; at East Lyme, Connecticut, shore roads were washed out; at Misquamicut and Weekapaug Beaches in Westerly, Rhode Island, shore roads were under several feet of sand; at North Kingston, Rhode Island, the bank and shore road were cut back; at Jamestown, Rhode Island, houses were deposited on the road; and at Wareham, Falmouth, Barnstable, and Martha's Vineyard in Massachusetts shore and beach roads were either covered with sand and debris, or destroyed. In addition to such road damage, many bridges were seriously damaged, as for examplo the Nanquacket and Stone Bridges in Tiverton, Rhode Island, and the Coggeshall Bridge in New Bedford, Massachusetts.

47. Shore protective structures. - Damage to shore protective structures was compartively moderate except at places such as Falmouth, Massachusetts, where seawalls and bulkheads were destroyed or seriously damaged and backfill eroded, and Salem, Massachusetts, where a heavy seawall was torn away at Hurley Point. In other instances, protective structures were overtopped and the property which they were designed to protect was seriously damaged, with little damage to the protective structure itself. Representative of the variety of minor damage to protective structures, most of which was incurred in Hurricane Carol,

was the damage to stone groins at Hawks Nest Beach in Old Lyme, Connecticut; damage to seawalls at Crescent Beach in East Lyme, Connecticut, at Narragansett, Rhode Island, and in the Clark Cove area of New Bedford, Massachusetts. Similar minor damage is exemplified by that to boulder revetment at Avery Point in Groton, Connecticut; by erosion behind the seawall at Stonington Point, Connecticut; and by damages to timber groins at Buttonwoods in Warwick, Rhode Island. Minor damages of this general nature were widely experienced along the coastal areas of Long Island, Connecticut, Rhode Island, and Massachusetts, as well as to a lesser extent in New Hampshire and Maine.

48. Channel shoaling. - Little accurate information is yet available as to the extent of shoaling caused by Hurricanes Carol and Edna however experience in the 1938 hurricane indicates that substantial shoaling may well have occurred in various navigation channels. Minor instances of shoaling known to have been caused by the 1954 hurricanes occurred at the Venetian Harbor entrance on the eastern shore of Connecticut, and in the Quonochontaug inlet in the south shore of Rhode Island.

49. Beach erosion. - In some instances changes in the appearance of particular beaches resulting from Hurricane Carol were striking. Along the eastern portion of the south shore of Long Island, beaches were breached and large sections of dunes cut through. At Hammonasset Beach in Madison, Connecticut, the landward edge of the sand beach

Beach damage. Breach in barrier beach. Hurricane Carol. Westhampton, L. I., New York.
New England-New York Region.

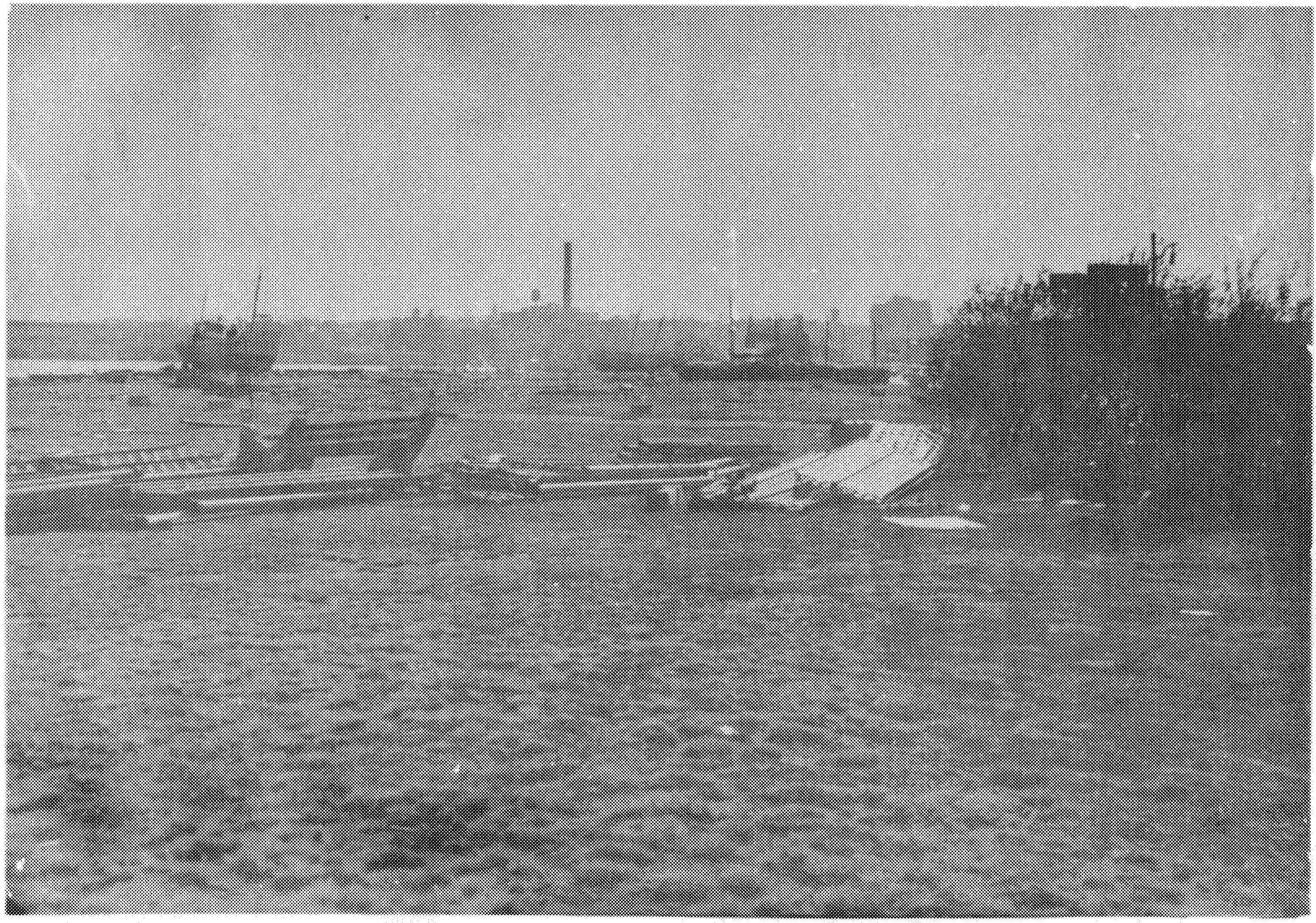
was reportedly extended about 40 feet inland over the marsh with an average depth of sand of one foot. In general, however, erosion of beaches resulting from wave attack was moderate. Along the Massachusetts shore, wave attack occurred generally at a higher level than the berms of beaches, with consequent erosion of bluffs, cliffs, and sand dunes rather than of the beaches themselves. Even in those areas receiving the brunt of Hurricane Carol's attack, specifically those areas extending westward from Chatham, along Nantucket and Vineyard Sounds, Buzzards Bay, Narragansett Bay, Block Island Sound, Fishers Island Sound, and Long Island Sound, erosion of beaches was not generally severe. Minor erosion, or accretion, occurred at a variety of localities. Representative of erosion was that of the sound end of Crescent Beach in East Lyme, Connecticut, and the accretion of Black Point Beach. At Napatree Beach, in Westerly, Rhode Island, there was a substantial movement of beach sand landward. More common, however, was the erosion of areas normally beyond the reach of wave attack. Heavy erosion along Cliff Walk in Newport, Rhode Island, ripped away huge unprotected sections of the walk. The erosion of dunes and the movement of large quantities of sand landward at Horseneck Beach in Westport, Massachusetts was also reported.

50. Works under construction. - Extensive public works were under construction in New England. Public highways were being built in unprecedented volume, military construction was at a high level, and public buildings, particularly schools, were being erected in

many communities. With great activity in public construction, it might have been expected that the intense winds and precipitation which occurred during the 1954 hurricanes would have caused much damage. The damage surveys conducted by Federal, State and municipal authorities did not, however, reveal the existence of any large amount of damage to works under construction. Except for isolated damages, such as washouts of embankments, minor damage to buildings and bridges under construction, and lost time, it appears that damage to works under construction was relatively minor. No separate estimates covering this type of damage are available.

51. Estimates of damage. - Estimates of damages to public property for New England are given in Table 85. Damage to public property on Long Island, New York resulting from Hurricane Carol amounted to an estimated $524,000 and from Hurricane Edna, $175,000. In addition, beaches and beach protective structures some of them public property, were seriously damaged by Hurricane Carol and to a lesser degree by Hurricane Edna. Total damages to beaches and beach protective structures attributable to Carol amounted to an estimated $475,000 and to Edna $80,000. In north-central and western New York State, damages to municipal property and to public highways and parks attributable to Hurricane Hazel have been estimated at $849,200.

52. Shipping. - Damages coincident with recent hurricanes have been particularly severe to fishing vessels, other commercial vessels, recreational craft and shore facilities servicing these



Vessel damage. Fishing vessels aground. Popes Island, Massachusetts. Hurricane Carol. New England-New York Region.

Table 85 - Summary of hurricane damages to public properties in New England, 1954, New England-New York Region

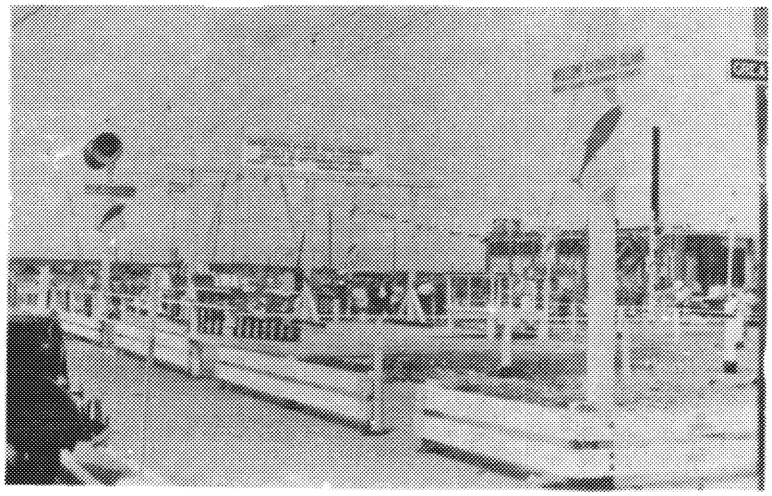
Location	Buildings	Bridges and Highways: Town 1/	Bridges and Highways: State	Seawalls, breakwaters and channels	Other public 2/	Total
Hurricane Carol						
Connecticut	$ 26,000	$ 439,000	$ 180,000	$ 487,000	$ 2,247,000	$ 3,379,000
Rhode Island	588,000	1,258,000	724,000	540,000	7,634,000	10,744,000
Massachusetts	328,000	2,568,000	3,143,000	389,000	22,191,000	28,619,000
New Hampshire	39,000	77,000	375,000	-	353,000	844,000
Maine	95,000	1,000	132,000	15,000	340,000	583,000
Totals	$1,076,000	$4,343,000	$4,554,000	$1,431,000	$32,765,000	$44,169,000
Hurricane Edna						
Connecticut	$ 4,000	$ 100,000	$ 45,000	-	$ 556,000	$ 705,000
Rhode Island	58,000	242,000	80,000	-	519,000	899,000
Massachusetts	22,000	406,000	-	-	529,000	957,000
New Hampshire	1,000	-	300,000	-	83,000	384,000
Maine	-	2,419,000	1,628,000	-	1,113,000	5,160,000
Totals	$ 85,000	$3,167,000	$2,053,000	-	$ 2,800,000	$ 8,105,000
Grand Total						$52,274,000

1/ Damage totals except for Massachusetts and Maine, include damage only to town highways located in coastal communities.

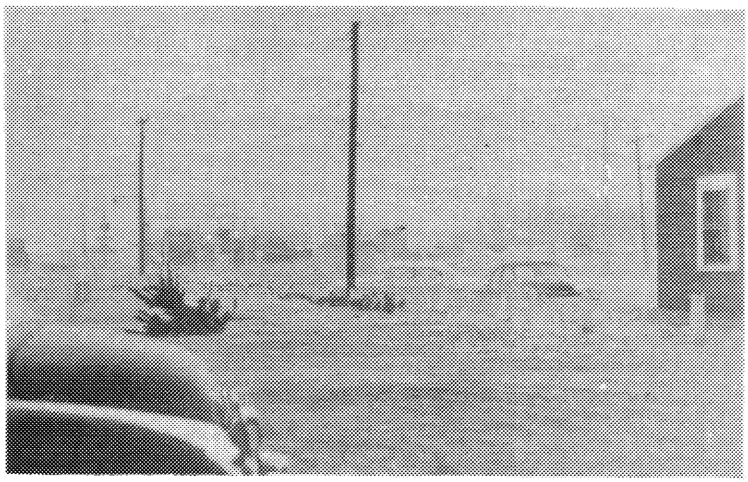
2/ Includes all estimates of damage which could not be segregated by specific item, and cost of cleanup and damage to military installations.

craft along the southern coast of New England and the Long Island shores. Losses by fishing vessels and recreational craft have been especially heavy.

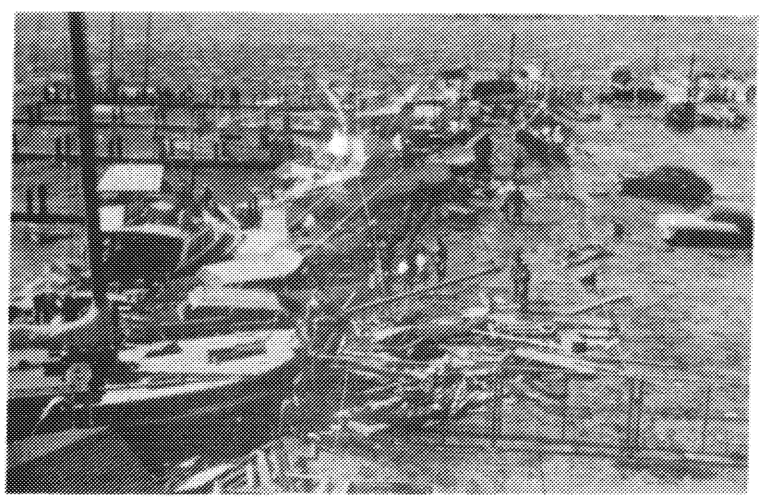
53. Commercial vessels. - Hurricanes Carol and Edna caused an estimated loss of over two and one-half million dollars in New England and Long Island to commercial vessels. About 140 vessels were wrecked and 455 damaged, in New England waters. Most of this damage was suffered by fishing vessels. In Massachusetts alone the loss amounted to about a million dollars with nearly half of this suffered by the fishing fleet at the port of New Bedford. In all, some 32 vessels were damaged at New Bedford to the extent of \$495,000 with the estimated losses ranging from \$2,000 to \$40,000 per vessel. Commercial vessels in Rhode Island, mostly fishing vessels, suffered losses totalling about \$650,000. Losses were incurred by large trawlers and numerous smaller vessels. Damages to commercial vessels in Connecticut totalled about \$390,000. Some \$250,000 of the total occurred at Stonington, Connecticut which is the home port for 80 percent of the fishing fleet in Connecticut. At Stonington, three vessels were sunk, one being a total loss, 16 were washed ashore, three were floating and out of commission, and two required dry-docking for repairs. In Maine damages to commercial vessels amounted to about \$450,000. A large percentage of this loss was suffered by the fishing fleet, small lobster boats and other small fishing craft. The smallest losses in New England waters were incurred by fishing vessels in New Hampshire where the total loss



Before: Assembly for 1954 U. S. Atlantic Tuna Tournament at Narragansett, R. I.



During: Boats riding at or above level of pier and autos awash.



After: Wrecked Tuna Tournament craft. Hurricane Carol. New England-New York Region.

was estimated to be $65,000. Much of this damage occurred in the ports of Hampton, Seabrook, Rye and New Castle. Damages to commercial vessels in Long Island waters amounted to an estimated $54,000 from Hurricane Carol and $3,000 from Hurricane Edna.

54. Small craft. - Recreational craft suffered extremely heavy losses during Hurricanes Carol and Edna at many points along the southern shores of New England particularly in the Narragansett Bay as a result of Hurricane Carol. It is estimated that over 750 pleasure craft were wrecked and more than 3,000 damaged. The value of these losses is an estimated $9,900,000. Many craft were driven ashore, swamped and pounded against the bridges and wharves. More than half of the U. S. Atlantic Tuna Tournament Fleet was sunk or damaged at Galilee, Rhode Island. Shore facilities such as piers, boat houses, yacht clubs and similar structures also received great damage, some being smashed beyond repair. In Long Island waters pleasure craft suffered damages estimated at $281,000 from Hurricane Carol and $88,000 from Hurricane Edna.

55. The estimated damage in New England waters to shipping by political subdivision and class is given in Table 86. Included in the over-all estimates are damages to private and commercial shore installations. No attempt has been made to give individual damage figures for Hurricanes Carol and Edna, but it is generally acknowledged that Hurricane Carol caused the most severe losses to shipping. Damages to commercial vessels which may have been caused by Hurricane Hazel have not been reported to the Committee. It is reported that Hurricane

Hazel damaged over 100 small craft in western Long Island waters, but the monetary loss is not known.

Table 86 - Shipping losses from Hurricanes Carol and Edna, New England, 1954, New England-New York Region

Location	Fishing vessels	Recreational craft	Total
Connecticut	$ 390,000	$ 1,000,000	$ 1,390,000
Rhode Island	650,000	5,000,000	5,650,000
Massachusetts	1,000,000	3,000,000	4,000,000
New Hampshire	65,000	150,000	215,000
Maine	450,000	750,000	1,200,000
Totals	$ 2,555,000	$ 9,900,000	$12,455,000

56. Utilities. - Utilities suffered varying degrees of damage from recent hurricanes. The following paragraphs set forth the effects of these hurricanes on water supply, sewerage, electric power, and communication systems. **Utility damages are summarized in Table 89b.**

57. Water systems. - On August 31, 1954, Hurricane Carol caused a large amount of damage to water systems, particularly in Rhode Island and eastern Massachusetts, although the number of systems and the monetary loss were not so large as during the 1938 hurricane. Losses were similar to those of 1938 and involved power losses, requirements for emergency equipment, tree damage, breakage of mains at river crossings, washouts of mains and service lines, contamination of water supplies by salt water and damages to buildings and equipment such as meters, electrical controls and motors and pumps.

Damaged recreational craft. Scituate Harbor, Mass. Hurricane Carol.
New England-New York Region.

58. Massachusetts reported the largest damage to water systems from Hurricane Carol. A total of 27 water systems reported damage and the total loss was estimated to be $195,000. In Rhode Island seven water systems were reported damaged and the loss was approximately $78,000. In Connecticut no damages to water supply systems were reported to the Department of Health and since this agency usually is informed when such damages occur it is assumed that the damage and dollar loss were minor. In Maine the only damage reported was at Belfast where less than $500 was expended for reservoir restoration. Other than temporary power failure in three communities, the only damage in New Hampshire occurred at Lancaster where the intake dam was washed out. Repairs to the dam and disinfection of the reservoir cost a reported $5,000. Vermont and New York (within the New England-New York Region) reported no losses to water supply systems from the August 31 hurricane.

59. Massachusetts was the only State reporting damages to water supply systems from Hurricane Edna (September 11, 1954). Six water supply systems in eastern Massachusetts reported damages, mostly due to power loss although in one instance silt entering the reservoir caused partial clogging of slow sand filters and at another the tubular well field was flooded. The total monetary loss, mostly for emergency and extra labor, was estimated by the State Department of Public Health as probably not in excess of $3,000.

60. None of the States reported any direct loss as a result of Hurricane Hazel which occurred on October 16, 1954. In New York,

a number of water supply systems suffered a temporary loss of power and had to resort to the use of auxiliary equipment. Where auxiliary equipment was not available storage capacities were adequate to avoid serious drops in water pressure. Table 87 summarizes the monetary loss to water supply systems caused by the hurricanes of 1954.

Table 87 - Summary of monetary damages to water supply systems by 1954 hurricanes, New England-New York Region

State	1954 August. 31	1954 September 11	1954 October 16
Connecticut	No damage	No damage	No damage
Maine	$ 500	No damage	No damage
Massachusetts	195,000	$ 3,000	No damage
New Hampshire	5,000	No damage	No damage
New York	No damage	No damage	No damage
Rhode Island	78,000	No damage	No damage
Vermont	No damage	No damage	No damage

61. Sewerage. - Hurricane Carol caused a considerable amount of damage to sewerage systems, particularly in Rhode Island and the Cape Cod area in Massachusetts. Flood waters caused the greatest amount of damage by flooding treatment plants and pumping stations necessitating repairs to or replacement of motors, pumps, engines, other equipment, switchboards, wiring and meters. Flood damage also required the repair and cleaning of buildings, treatment units and sewerage systems. There was also minor damage reported for treatment plants by wash from the heavy rain and wind damage to

trees. A number of sewerage systems in Maine were damaged and one industrial waste storage lagoon in New Hampshire was washed out. No damages to sewerage systems were reported from Connecticut, Vermont, or New York.

62. Monetary damages totalling $215,200 were reported for 12 sewerage systems in Rhode Island most of which occurred at the East Providence sewage treatment plant. Five sewerage systems in Massachusetts reported a total estimated damage of $153,900 and a number of others reported minor damage only which probably did not exceed a total dollar loss of more than $5,000. Reports on monetary damage to sewerage systems in Maine did not specify which of the 1954 hurricanes caused the loss but the Maine Department of Health and Welfare reports that the most damage occurred during the September 11 hurricane. On this basis, it is estimated that damage to sewerage systems in Maine during Hurricane Carol probably did not exceed $10,000. The loss resulting from the washout of the industrial waste storage lagoon in New Hampshire was reported to be $35,000.

63. Maine and Massachusetts were the only two States reporting damages to sewerage systems from Hurricane Edna (September 11, 1954). In Massachusetts there was minor damage from heavy rains by flooding sewerage systems and treatment works and the State Department of Public Health estimates that the total loss in all communities probably did not exceed $2,000. In Maine, where one center of the storm struck, damage to sewerage systems was more severe, including broken sewer lines, collapse of trunk sewers, washouts, damage to

outfall sewers by wave action, and the clogging and filling of a large number of sewers and catch basins by silt and debris. A total of 32 communities reported damages to sewerage systems from Hurricanes Carol and Edna, most of which were damaged by the latter. A total monetary loss of $92,800 was reported for the two hurricanes of which it is estimated that approximately $82,800 was caused by Hurricane Edna on September 11.

64. None of the States reported damages to sewerage systems from Hurricane Hazel (October 16, 1954). A number of treatment plants in New York had a temporary loss of power which probably did not result in any direct monetary loss. Table 88 summarizes the monetary loss to sewerage systems caused by the hurricanes of 1954.

Table 88 - Summary of monetary damages to sewerage systems by 1954 hurricanes, New England-New York Region

State	1954 August 31 (Carol)	September 11 (Edna)	October 6 (Hazel)
Connecticut	Negligible	No damage	No damage
Maine	$10,000 2/	$82,800 1/	No damage
Massachusetts	153,900	2,000 2/	No damage
New Hampshire	35,000	No damage	No damage
New York	No damage	No damage	No damage
Rhode Island	215,200	No damage	No damage
Vermont	No damage	No damage	No damage

1/ A total loss of $92,800 was reported for the two hurricanes of August 31 and September 11, most of which was caused by the latter.

2/ No individual reports available but estimated by the Department of Public Health not to exceed this amount.

65. <u>Communication utilities.</u> - The greatest damage to communication utilities occurred to the two major New England telephone companies and their subsidiaries during Hurricanes Carol and Edna. Some 250,000 telephones were reported out of service in Massachusetts, Rhode Island, New Hampshire and Maine. By far the preponderant part of the damage was caused to poles and lines. In north-central and western New York State, Hurricane Hazel caused damages to communication utilities totaling an estimated $160,000. Customers affected by loss of telephone service numbered 32,900. About half of this damage occurred in the area of north-central New York centered on Syracuse.

66. <u>Power utilities.</u> - It is estimated that damage to utility generating plants, transmission and distribution facilities in New England and New York State 2/ were in excess of 14 million dollars and that during the three 1954 hurricanes, almost 4 million customers were affected. Following Hurricanes Carol and Edna, restoration to service in the coastal areas varied from one to ten days, while that following Hazel required one to five days. The location and routing of essential equipment and material to repair or replace damaged facilities taxed the combined efforts of utilities, manufacturers, jobbers and transportation channels.

2/ Includes portion of New York outside New England-New York Region.

67. The principal utilities affected by Hurricanes Carol and Edna were those in the coastal areas of New England and New York. Eighteen utilities in New England and four in New York State furnished data on damages from the three hurricanes.

a. New England. - The eighteen utilities, which furnished data on Hurricanes Carol and Edna, including the few affected by both these storms and also Hurricane Hazel, provide almost 90 percent of the peak load requirements of New England.

b. New York. - The four utilities which furnished data on damages incurred in the 1954 hurricanes supply over 90 percent of the peak load requirements of New York State.

67a. Analysis of the damage incurred in Hurricanes Carol and Edna indicates that generating stations were affected in only a few instances. Transmission lines were affected to only a moderate degree in heavily struck areas. However, distribution circuits suffered heavily and it is estimated that over 85 percent of total damages and outages resulted from failure in this branch of utility plant. Some of the very large utilities were unable to break down accurately total dollar damages between Hurricanes Carol and Edna inasmuch as the latter followed so closely upon the former that repairs, and in many instances surveys of affected equipment, had not been completed before essentially the same work had to be carried out again.

a. New England. - Total reported dollar damages sustained by the 18 New England utilities as a result of the three storms aggregated approximately $10,650,000. Although Hurricane Edna caused in some instances more damage than Carol, particularly in parts of the State of Maine, the greatest outage of service to consumers and the maximum loss of load for the entire group of eighteen utilities occurred immediately after Carol had passed through. This storm shut off about 1,750,000 customers aggregating nearly 1,760,000 kilowatts of non-coincident load. It is estimated that between 4,500 and 5,000 distribution system poles required replacement or repair in New England due to Carol and about 2,000 to 2,500 to Edna. The total dollar damage and estimated customers affected with an estimate of the load dropped by States for the three hurricanes is shown in Table 89.

Table 89 - Direct damages, customers affected, and load dropped 1954 hurricanes, (18 utilities solicited comprising 90 percent of New England load) New England-New York Region

State	Estimated direct damages 1/	Estimated customers affected	Estimated load dropped
		Number	kw
	Hurricane Carol		
Connecticut	$ 475,500	213,000	332,000
Rhode Island	1,119,400	258,000	321,000
Massachusetts	5,359,600	958,000	800,000
New Hampshire	658,500	115,000	95,000
Maine	720,000	210,000	207,000

Table 89 - (Continued)

State	Estimated direct damages 1/	Estimated customers affected	Estimate load dropped
		Number	kw
		Hurricane Edna	
Connecticut	$ 198,000	116,000	89,000
Rhode Island	251,600	101,000	102,000
Massachusetts	1,237,400	483,000	375,000
New Hampshire	151,500	36,000	31,000
Maine	380,000	145,000	138,000
		Hurricane Hazel	
Connecticut	98,100	59,500	53,000
Total	$10,649,600	2,694,500	2,563,000

1/ Indirect losses (power production and customer losses) estimated to be about $5,324,800.

b. New York. - Total reported damages sustained by the four New York utilities as a result of 1954 hurricanes aggregated approximately $3,560,000. Although the hurricanes, Carol and Edna affected principally Long Island, the Metropolitan Area of New York City, Hurricane Hazel caused considerable trouble in this area and in west central New York State. The maximum consumer outage for the area served by the four utilities occurred with Hurricane Hazel when 720,000 customers were cut off and about 600,000 kilowatts of non-coincident load. In New York the total number of distribution poles damaged or replaced was of the order of 350 to 400 in Carol, 250 to 300 in Edna, and 850 to 1000 in Hazel. Estimates of total dollar damage and customers cut off for the three hurricanes with an estimate of the load lost are shown in Table 89a.

Table 89a - Direct damages, customers affected, and load dropped, 1954 Hurricanes, (4 utilities solicited comprising over 90 percent of New York load) New England-New York Region

State	Estimated direct damages 1/	Estimated customers affected Number	Estimated load dropped KW
		Hurricane Carol	
New York	$1,395,000	375,000	425,000
		Hurricane Edna	
New York	544,000	132,500	170,000
		Hurricane Hazel	
New York	1,620,000	720,000	600,000
Totals	$3,559,000	1,227,500	1,195,000

1/ Indirect losses (power production and customer losses) estimated to be about $1,779,500.

Table 89b - Hurricane damages to utilities in coastal communities of New England, 1954, New England-New York Region

Hurricane Carol

Location	Municipal utilities	Communication facilities	Private power 1/ plants and transmission	Total
Connecticut	$ 115,000	$ 638,000	$ 713,250	$ 1,466,250
Rhode Island	259,000	1,200,000	1,679,100	3,138,100
Massachusetts	492,000	5,100,000	8,039,400	13,631,400
New Hampshire	-	675,000	987,750	1,662,750
Maine	20,000	900,000	1,080,000	2,000,000
Subtotal	886,000	$ 8,513,000	$12,499,500	$21,898,500

Hurricane Edna

Location	Municipal utilities	Communication facilities	Private power 1/ plants and transmission	Total
Connecticut	$ 8,000	$ 360,000	$ 297,000	$ 665,000
Rhode Island	33,000	1,200,000	377,400	1,610,400
Massachusetts	40,000	5,100,000	1,856,100	6,996,100
New Hampshire	-	675,000	227,250	902,250
Maine	6,000	900,000	570,000	1,476,000
	$ 87,000	$ 8,335,000	$ 3,327,750	$11,649,750

Hurricane Hazel

Location	Municipal utilities	Communication facilities	Private power 1/ plants and transmission	Total
Connecticut			$ 147,150	$ 147,150
Totals	$ 973,000	$16,748,000	$15,974,400	$33,695,400

1/ Includes estimates of direct and indirect damage for both coastal and interior areas.

68. Transportation facilities. - Transportation facilities suffered from the effects of 1954 hurricanes. The railroads were particularly hard hit suffering total damages of more than $2,500,000, with $1,995,000 in New England and the remainder in New York State. Washouts, loss of communication and switching, and damage to bridges and culverts, were heavy for the coastal lines. Some branch lines remained out of service for extended periods but in general, main lines were operating normally in less than one week. Airlines suffered approximately $300,000 damage from Hurricane Carol. This damage was principally to ground installations and aircraft. Loss of income, added personnel and operation costs accounted for only 25 percent of the total. Bus companies suffered relatively minor direct damages, most of their loss being due to loss of patronage. Damages to railroad facilities in New England by state are given in Table 90.

Table 90 - Damages to railroad facilities in New England from 1954 hurricanes, 1/
New England-New York Region

Location	Hurricane Carol	Hurricane Edna	Total
Connecticut	$ 300,000	$ 15,000	$ 315,000
Rhode Island	525,000	15,000	540,000
Massachusetts	206,000	185,000	391,000
New Hampshire	69,000	40,000	109,000
Maine	58,000	582,000	640,000
Totals	$1,158,000	$ 837,000	$1,995,000

1/ Central Vermont R. R. not included

69. It is notable that the greatest damage to railroads occurred in Maine during and following Hurricane Edna. This damage resulted largely from washouts induced by the heavy precipitation which occurred in Maine at the time of this storm.

70. Military installations. - Military installations located in southern New England suffered heavily, principally those which were subjected to tidal flooding. Others suffered relatively minor damage such as loss of roofing, washout of roads and erosion of runways. The Navy and Air Force were well prepared for the storms and utilized their own forecast alert to send ships to sea and to remove aircraft to fields outside the damage area prior to the storm. Damages to military installations in New England are included in the estimates of public damage given in Table 85.

71. Commercial installations. - Damages to commercial installations include damage to the service industries; warehouses, stores, restaurants, banks, and office buildings. Great damage to these installations occurred from the tidal flooding occasioned by Hurricane Carol. By far the largest loss occurred in the Providence, Rhode Island area as tidal waters overflowed the commercial center of the city. Cleanup of the city following Hurricane Carol involved the destruction of about 500,000 cases of canned goods, 48 freight carloads of fruit and produce, prescription drugs and medicines valued at $300,000, 500,000 pounds of flour, 100,000 pounds of meat, 40,000 pounds of fish, 5,000 cases of malt beverage, 15,000

Waterfront property damage. Narragansett Pier, Narragansett, Rhode Island.
Hurricane Carol. New England-New York Region.

cases of carbonated beverages, and 2,500 cases of liquor spirits. In addition, stocks of shoes, dry goods, furniture and other items were severely damaged or rendered worthless by the salt water. Substantial damages occurred to commercial establishments in other localities, the greater part of the damage being attributed to tidal flooding.

72. The estimated damage to commercial installations in New England by political subdivision and by storm is given in Table 91.

Table 91 - Damages to commercial installations in New England from hurricanes, 1954 1/
New England-New York Region

Location	Hurricane Carol	Hurricane Edna	Total
Connecticut	$ 2,752,500	$ 489,000	$ 3,241,500
Rhode Island	44,589,000	941,000	45,530,000
Massachusetts	5,063,000	539,000	5,602,000
New Hampshire	280,000	-	280,000
Maine	317,000	197,000	514,000
Totals	$ 53,001,500	$ 2,166,000	$55,167,500

1/ Includes damages to commercial properties situated in coastal communities only.

73. Of the above commercial damages suffered during the two storms, $39,652,000 occurred within the City of Providence, Rhode Island, $1,545,000 at Newport, Rhode Island, $1,500,000 at New Bedford, Massachusetts, and $1,359,000 at New London, Connecticut. Thus, these four cities account for about 77 percent of the total commercial loss occasioned by these storms in coastal areas of the region.

74. Commercial installations and industrial plants along shore areas in Long Island, New York were also hit severely by wind and water accompanying 1954 hurricanes especially Hurricane Carol, which produced damages to these commercial installations of an estimated $909,000. Hurricane Edna caused damages amounting to $30,000. Estimates of commercial damage in the remainder of the New York State portion of the region from Hurricane Hazel are not available at this time.

75. Industrial property. - Some of the areas along the southern coast of New England are highly developed for industrial purposes. Manufacturing plants are concentrated in Stamford, Bridgeport, New Haven, Norwalk, and Stonington in Connecticut, Westerly and Providence, Rhode Island, and Fall River and New Bedford in Massachusetts. Those facilities situated adjacent to tidal waters suffered tremendous losses particularly in the area east of New London. By far the greatest concentration of damage occurred in Providence, Rhode Island, New Bedford, Massachusetts, and adjacent areas. These areas were also among those where the tidal heights (above mean high water) were the greatest. Damages to industrial plants in coastal areas of New England by states, are given in Table 92 separately for each storm.

76. Seventy percent of the total industrial loss in coastal areas amounting to over $27,000,000, occurred in the Providence, Rhode Island, and the New Bedford, Massachusetts areas. These

Industrial property damage. Hurricane Carol. New Bedford, Massachusetts.
New England-New York Region.

Table 92 - Hurricane damages to industrial plants in New England, 1954. 1/
New England-New York Region

Location	Hurricane Carol	Hurricane Edna	Total
Connecticut	$ 5,339,000	$ 205,000	$ 5,544,000
Rhode Island	13,938,000	591,000	14,529,000
Massachusetts	16,958,500	867,000	17,825,500
New Hampshire	99,000	21,000	120,000
Maine	32,000	24,000	56,000
Totals	$ 36,366,500	$1,708,000	$ 38,074,500

1/ Includes damages to industries situated in coastal communities only.

losses were predominantly due to tidal flooding with almost 90 percent of the industrial damage in these two areas being attributed to this cause alone.

77. Agricultural damages. - Agricultural damages, while generally not as severe as other classes of damage, were experienced in varying degree throughout the New England-New York Region. Agricultural damages sustained in the State of Maine from Hurricanes Carol and Edna amounted to an estimated $10,000,000. Losses in Massachusetts from the same two storms, largely from destruction of crops, amounted to $6,840,000. The loss in New York State from 1954 Hurricanes was estimated to be $5,104,000, primarily in damages to farm buildings. Total damages for the region amounted to an estimated $29,285,100. Table 93 summarizes 1954 hurricane damages throughout the region by type of damage for each state. The classes of agricultural damage resulting from hurricanes are as follows:

a. Homes and buildings. - For the most part, damages were confined to roofs and structurally weak buildings. An exception was the loss of poultry houses which were bodily removed. A number of silos were blown over or put out of use. In most instances of silo loss the structures were weak and the hurricane simply speeded up the task of replacement. Entire buildings were removed in some areas, particularly in Rhode Island and a few other hard hit sections.

b. Machinery. - Relatively little damage to machines was reported. This would be expected in view of the relatively minor building damage, and the few buildings entirely destroyed.

c. Orchards. - Damage to the 1954 apple crop was heavy, up to 65 percent of apples on the tree (most McIntosh variety) being blown to the ground. Relatively few of the wind-blown apples could be sold as grade one fruit. Also, a small percentage was too immature for any use. Most of the remaining wind-blown apples were sold for local use or were converted into cider. Efforts of the local food stores to market the apples were very successful, and were a very important factor in keeping losses to a minimum. Apples remaining on the trees suffered some damage from winds, but many of them made additional growth and produced a higher than average proportion of grade one fruit. Relatively few trees were blown down or destroyed.

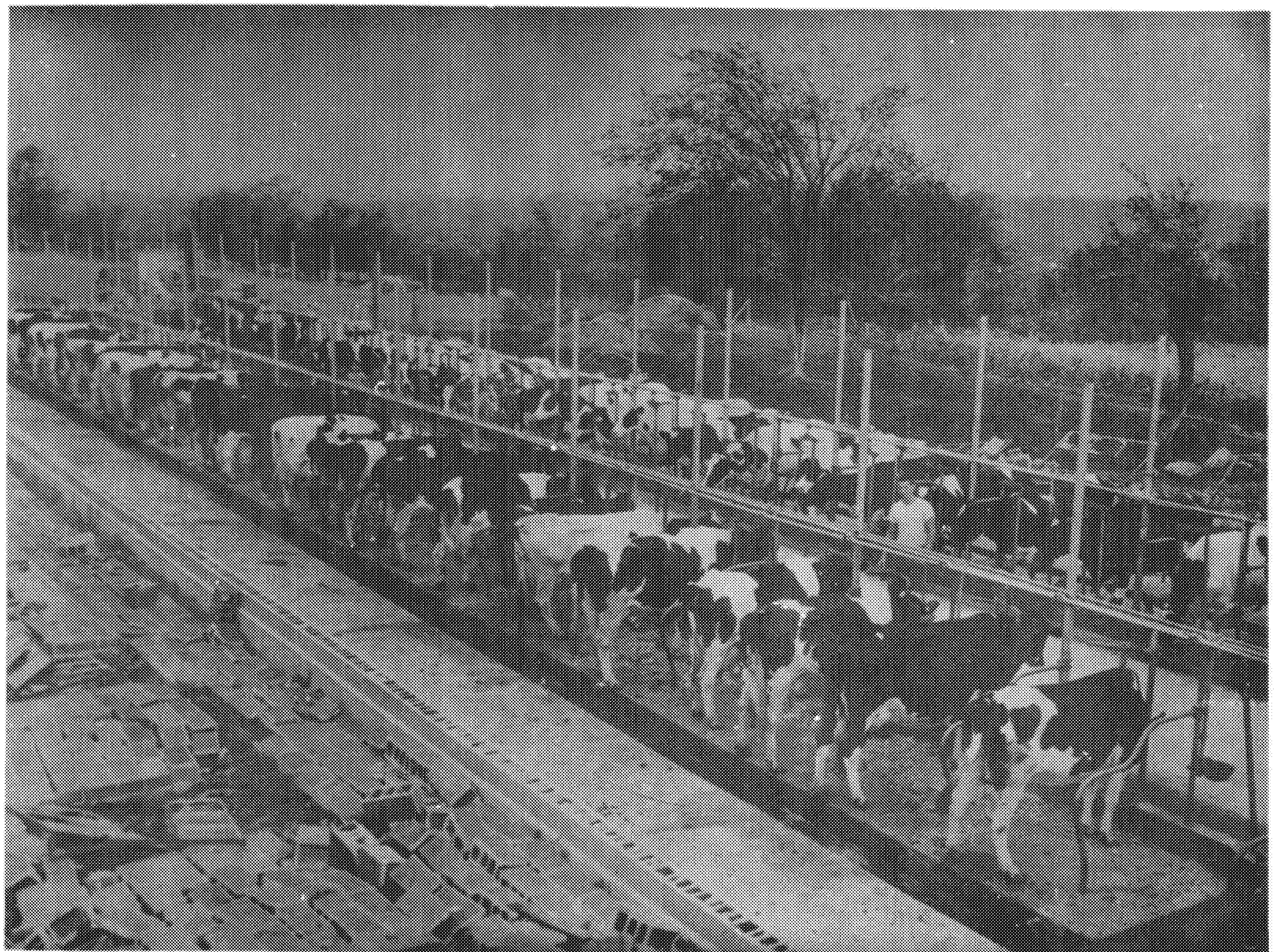
d. Tobacco. — Damage to unharvested tobacco in Massachusetts and Connecticut was high. About 10 percent of the open field crop had not been harvested at hurricane time, and about half of this was completely lost. Losses to shade tobacco growers in Connecticut were heavy. About 15 percent of the crop was not harvested at time of hurricane, and at least half of this was left valueless. Most of the shade tobacco cloth had no salvage value because of tearing. Comment from the field was that the tobacco cloth in 1954 was of poorer quality than usual, and doubt was expressed whether the cloth would have had any salvage even without hurricane damage.

e. Other crops. — Heavy rains in connection with the hurricanes caused some delay in harvesting operations because of wet land conditions. They also contributed to spread and increase in severity of late potato blight. Washing of soil uncovered significant quantities of potatoes, leaving them exposed to the sun, which resulted in loss of salability. Extra costs for harvesting silage corn were cited because the corn was partially blown down, and in more than one direction. There was considerable loss of quality in the late sweet corn crop in Maine, and a portion of the crop was considered unfit to harvest. Growing conditions prior to the hurricane had been relatively unfavorable, and the quality of crop was definitely below average. Detailed costs representing the above crop items and factors are not available. It is apparent, however, that the direct and indirect damages and costs were of considerable magnitude.

f. Livestock and fowl. - Losses of livestock, except poultry, were of small consequence. In several instances poultry houses were blown away. When this happened, birds were killed immediately or were scattered or lost. Some recovery was possible. Highway conditions resulting from heavy rains in the State of Maine prevented hauling of poultry food and the regular marketing of eggs and broilers.

g. Forests and lumber. - In general, there was less timber blown down than in the 1938 hurricane. Local exceptions to this occurred, however, and in many locations salvage operations were given first priority. Blown timber is reported to be worth some four dollars per thousand board feet less than standing timber, and the damage estimates were made on that basis. Blow-down of all types of trees created a removal problem on fire-access roads.

78. Foodstuffs. - Hurricane Carol was responsible for a dollar loss of foodstuffs of approximately $6,700,000. This resulted largely from tidal flooding and loss of power at food establishments and private homes with the largest losses being incurred at Providence and other waterfront areas in Rhode Island. In all, 2,323 food establishments of all categories in Rhode Island were reported to



Agricultural damage. Dairy barn destroyed. Hurricane Carol. Somerset, Massachusetts. New England-New York Region.

Table 93 - Summary of agricultural damages from 1954 hurricanes, New England-New York Region

State	Type of Damage						
	Buildings	Equipment	Crops	Livestock	Timber 2/	Other	Total
Maine	-	-	-	-	-	-	$10,000,000
New Hampshire 1/	$1,568,500	$11,000	$566,300	$29,500	$186,500	$106,500	2,468,300
Vermont	100,000						100,000
Massachusetts	1,100,000	-	5,500,000	-	240,000	-	6,840,000
Rhode Island	716,100	29,800	1,133,800	32,100	-	-	1,911,800
Connecticut	-	20,000	2,841,000	-	-	-	2,861,000
New York	4,605,500	99,500	173,000	124,000	102,000	-	5,104,000
TOTAL	$8,090,100	$160,300	$10,214,100	$185,600	$528,500	$106,500	$29,285,100

1/ No damages reported from Carroll, Cheshire and Coos Counties.

2/ Represents net loss figure based on salvageable values.

have suffered loss of foodstuffs by spoilage or contamination with a total dollar loss of $3,145,825. In addition to losses at food establishments, it was estimated that approximately $2,000,000 worth of food in private homes was lost due to extended power failure, most by spoilage of frozen foods stored in home freezers. In Massachusetts hurricane damages to foodstuffs were confined principally to the eastern part of the State, with most occurring in the Cape Cod area. Approximately 1,500 food establishments in Massachusetts lost foodstuffs having a dollar value estimated to be $1,200,000. The value of foods lost in homes due to power failure probably did not exceed $100,000.

79. In Connecticut the greatest damage to foodstuffs was caused to food establishments in those areas bordering the waterfront from Branford east to the State line, with the greatest damage occurring in the New London-Groton-Stonington area. It is estimated that 100 food establishments in Connecticut lost foods from hurricane damage that had a dollar value of approximately $250,000. Maine and New Hampshire had little loss of foods due to Hurricane Carol. The value of foods lost was caused by damage to $5,000 in each State. Most of this loss was caused by damage to food in homes due to temporary power failure. Damage to foodstuffs in Vermont was reported to be insufficient to note.

80. Foodstuff losses in the New England-New York Region caused by Hurricanes Edna and Hazel were reported to be negligible.

81. <u>Drug establishments.</u> - Drug establishments suffered a large loss from damages to medicines and related products caused by Hurricane Carol. Damage to drug establishments was greatest in Rhode Island where a total of 26 establishments of all types (retail, wholesale and manufacturing) reported losses, 16 of these establishments being in Providence. The total dollar loss to drug establishments in Rhode Island was reported to be $323,000. In Massachusetts eight drug establishments, mostly on Cape Cod, reported losses estimated at $200,000 from damages caused by Hurricane Carol. Along the waterfront in eastern Connecticut six drug establishments reported hurricane damages to stocks that resulted in a dollar loss estimated not to have exceeded $50,000. In all the other States in the region the damages to drug establishments by Hurricane Carol were reported to be very minor.

82. Losses to drug establishments caused by the Hurricane Edna and Hazel were reported to be negligible.

83. <u>Fisheries and wildlife.</u> - In addition to the damages to fishing vessels, the fishing industry suffered a severe blow through the destruction of docks, buildings, plants, nets, traps, pots, and other gear. The loss of stocks of fish and shellfish on hand and the unemployment of both men and equipment also resulted in great economic losses to the industry.

84. In Rhode Island the most serious damage resulted from the temporary loss of the Point Judith Fisherman's Cooperative dehydrating plant. Damages to buildings and equipment plus the losses of wages and profits during the period the plant was out of operation totaled more than $300,000. The Shellfish Company at Wickford suffered an estimated loss of $60,000. The pound net fishery of Rhode Island was completely wiped out with an estimated loss of $90,000. The lobster fishery lost an estimated $48,500 in pots, lines, and gear. A similar loss to the shellfishery was placed at about $14,200. The losses to the commercial fishery in Rhode Island totaled $830,400.

85. In Provincetown, Massachusetts, the traps or pound nets were more extensively damaged than traps or pound nets in any other port in the State. Twenty-five nets with a total estimated value of $107,000 were lost. Eight nets at North Truro and one net at Sandwich were destroyed. These nets were estimated to be worth about $31,000. In addition, the loss resulting from these traps being out of water was estimated to be $20,000 per week for the months of September and October.

86. At New Bedford, six dealers suffered from abnormally high tides resulting in destruction to their shore establishments. In addition three marine railways suffered considerable damage. The total estimated damage in New Bedford was $311,000. The production loss in this port was estimated at $11,600. The total fishing damages in Massachusetts, not including damages to fishing vessels, were estimated at $769,000.

87. In Connecticut, damages to commercial fishing gear and nets were estimated to total over $157,500. No data are available as to losses caused by unemployment of boats, gear, and fishermen.

88. Damages to fishing gear in Maine were extremely heavy. According to the estimates, Hurricane Carol caused a loss of $770,000 to traps and weirs, a loss of $100,000 in live lobsters which were stored awaiting shipment and $30,000 in damages to miscellaneous items. Hurricane Edna which struck the eastern section of the coast, caused damages estimated at $900,000 to traps, weirs and other gear. The loss of live, stored lobsters was estimated at $100,000 and miscellaneous damages, largely the result of heavy rains, were estimated at $50,000. Total losses in Maine were over $2,000,000.

89. In New Hampshire, the loss in traps and other gear was estimated at $30,000. This represents about 25 percent of the total of all commercial fishing gear in the State.

90. No data are available as to the effects of hurricanes on fish stocks or the fishing grounds. All indications are, however, that little if any damage occurred.

91. There was little over-all loss to shellfish areas as a result of the hurricanes. Disruption of sewerage systems during Hurricane Carol in Rhode Island resulted in the closure of a total of 11,000 acres of shellfish beds for periods of three to five weeks. Disruption of a pumping station at New Bedford, Massachusetts caused the overflow of raw sewage which resulted in the closure of another shellfish area.

Localized areas, where bottom conditions allowed sand to be washed readily, suffered some damage but the totals, both acreages and losses, are unknown. Considerable destruction of bay scallops, both seed and adult, occurred in the area at the head of Buzzards Bay in Massachusetts. Damage was also reported to oyster and quahog grants in the same general area and in the Town of Falmouth. The estimated total losses in both areas would exceed $75,000.

92. Of some importance in regard to the fisheries was the effect of hurricanes on the activities allied with the commercial fisheries. The research activities of both State and Federal agencies were hampered and, in some cases, set back for a long period of time. Research facilities of the Fish and Wildlife Service suffered estimated damages of over $5,000. No data are available for State marine facilities. The principal damage to inland fresh-water facilities was due to the floods accompanying the hurricanes with lesser damage from winds.

93. The only data available in regard to State fish hatcheries are those reported in Maine. Eleven of these units were damaged to some extent with the total loss estimated at $44,000. Extensive damage occurred to the boat liveries and charter and party boats which cater to the marine sport fishermen. No total damage figures are available, but it is known that most of the boat liveries lost a good share of their rental boats, in one case 29 out of 30, and buildings and docks were extensively damaged. One case was noted where

a bait and tackle shop was completely destroyed with a total loss of over $15,000.

94. Hurricane damage to wildlife was not extensive. Although wildlife food supplies were damaged to a considerable extent, with up to 75 percent loss on the five National Wildlife Refuges in the region, no lasting effects were noted. Most of the damage to dams, dikes, roads, and trails on wildlife management areas was caused by floods. In addition, silting of aquatic foods was noted in such waterfowl concentration points as Merrymeeting Bay, Maine, and in Narragansett Bay, Rhode Island. No estimate of total damages to wildlife is available at this time.

95. Damage to private and personal property. - The damage sustained by private and personal property in hurricanes is widespread, serious, and very difficult to estimate in its full extent. In innumerable cases, such damage is probably sufficiently minor to escape being reported or being observed by investigators; and in other cases, as in the damage done to personal effects in the flooding of cellars, for example, it is impossible to evaluate losses in monetary terms. In general, major private property damage may be classified under three headings; that occurring to homes and fixtures; that occurring to automobiles; and that occurring to trees and shrubbery. Destruction of homes is greatest in coastal areas which are subject to tidal flooding, for in these areas large numbers of homes are completely demolished by the extreme tides, and many more inevitably suffer highly serious water damage, as well as damage from wind. In interior areas, however,

probably few houses escaped some minor damage consisting of the loss of shingles, screens, porches, or other loosely attached fixtures. Similarly, damage to automobiles is overwhelmingly greatest in these areas subject to flooding, where large numbers of automobiles are inundated. In all areas, however, automobiles are vulnerable to flying debris and falling trees, suffering damages varying from minor dents to almost complete demolition. In all areas, trees, shrubs and other plants suffer severely. The high winds of hurricane force uproot thousands of trees, damage many more severely, and destroy shrubs and smaller plants.

96. Destruction of private property in Hurricane Carol was greatest in coastal areas subject to tidal flooding, and damage was greatest along the southern New England coast. The Narragansett Bay area in Rhode Island, and the coast of Massachusetts between Westport and the Cape Cod Canal received the most concentrated damage. In some communities along the shorefront, roads and cottages were almost totally destroyed for the second time in 16 years, having undergone similar destructive attack in 1938. In many shore areas, automobiles suffered extensive damage from both wind blown debris and water. Although less extensive in inland areas, damages were severe both to homes and to automobiles, and in both coastal and inland areas trees, shrubs and plants suffered considerably from high winds.

97. The destruction of homes in Hurricane Carol was staggering. Uncounted cottages and other structures were demolished by the accompanying flood with only piles of rubble left. Cottages nearest

Residential property damage. Wareham, Massachusetts. Hurricane Carol.
New England-New York Region.

the water were generally smashed to pieces, or lifted bodily from their foundations and hurled against cottages to the rear. In some cases, the wind demolished buildings prior to the onslaught of the tidal flood. Further inland and beyond the reach of the tide, the wind ripped off screens, doors, roof coverings, shutters, and almost every other loose object. In all areas, either as a result of tidal flooding or to a lesser extent as a result of torrential rains, thousands of cellars were flooded with consequent damage to heating systems and to personal effects. Tidal flooding accounted for the greatest proportion of destruction. Even well-constructed houses were unable to withstand the force of the waves. Buildings situated in protected locations but within reach of the water suffered extreme damage as we salt water rose above floor level.

98. The extent and type of damage is indicated by the early reports of damage in Rhode Island, where 620 single homes were estimated to have been destroyed, 888 to have suffered major damages, and over 4,000 to have suffered minor damages. Similar early estimates in Massachusetts indicated almost 800 buildings destroyed, slightly more suffering major damages, and over 2,600 suffering minor damages. Representative of damage occurring to homes along the Connecticut coast is the extensive damage to trailers, tents, and other portable houses at Hammonasset Beach; destruction at Westbrook and Old Saybrook where the tide floated away some 20 to 30 cottages in each town; in East Lyme, where the sea ripped the fronts off a dozen houses, and tore off both front and rear of some others; and at Stonington where

most of the 150 cottages were damaged, some 28 of them being demolished. In Rhode Island, where destruction was greatest, examples of the degree of damage were found at Misquamicut where in two miles of beach only four of 200 cottages remained upright; in South Kingston, where some 370 cottages were reported destroyed and between 1,000 and 1,100 damaged; at Narragansett, where 212 were destroyed and over 500 more damaged; and at Tiverton, where four homes were washed away and 50 more badly damaged. In Massachusetts, destruction was most staggering in the Buzzards Bay area. At Fairhaven, some 130 cottages and 35 homes were wrecked beyond repair and 200 or more were damaged, with the hardest hit areas being at Soontiout Neck and West Island. At Mattapoisett, 300 summer homes were reported demolished and 300 more seriously damaged. At Wareham, Bourne, and Falmouth likewise, destruction was exceptionally great, some 363 cottages being destroyed and 600 more damaged at Wareham alone.

99. As with other types of property, damage to motor vehicles was due principally to tidal flooding. Although a large number of automobiles were destroyed by falling trees, this was insignificant compared with the thousands of vehicles damaged or destroyed by tidal flooding. Hurricane Carol reached the coastal area of southern New England in the morning after most commuters had parked their automobiles. In Providence alone over 5,000 vehicles were reported to have been affected by tidal flooding. Many others suffered damage

Private property damage. Crescent Beach, Mattapoisett, Massachusetts. Hurricane Carol.
New England-New York Region.

at other coastal cities and towns when they were trapped in tidal waters. No complete estimates of damage to motor vehicles are available.

100. Privately-owned trees and shrubs suffered wind damage comparable to similar damage on publicly-owned land, but estimates are far from being all inclusive. Privately-owned forest lands received extensive damage but no estimates of damage are included in the summary presented in Table 94.

Table 94 - Private property damage from 1954 hurricanes in New England, 1/ New England-New York Region

Location	Hurricane Carol	Hurricane Edna	Total
Connecticut	$13,242,000	$2,687,000	$15,929,000
Rhode Island	13,913,000	1,616,000	15,529,000
Massachusetts	23,015,000	1,343,000	24,358,000
New Hampshire	954,000	22,000	976,000
Maine	580,000	217,000	797,000
Totals	$51,704,000	$5,885,000	$57,589,000

1/ Includes damages to private and personal property within coastal communities only.

101. Private property in coastal areas of Long Island, New York also suffered large losses as a result of Hurricane Carol and Edna. Hurricane Carol which caused damages to private property at an estimated $1,977,000 was particularly devastating. Residential property damage from Hurricane Edna amounted to about $104,000. Residential and commercial property damages in the New York State portion of the region resulting from Hurricane Hazel amounted to an estimated $2,140,000. More than 85 percent of these damages occurred in the

north-central area of the State centered on Syracuse. Property damage in New England resulting from Hurricane Hazel was less than $100,000. Total damages on Long Island resulting from Hurricane Hazel were an estimated $125,000.

102. Employment losses. - The losses from unemployment in New England have been included where possible in the appropriate damage figures. Estimates by States of the employment time lost by workers as a result of Hurricanes Carol and Edna are as follows: 1,500 workers displaced for an average duration of 16.2 days in Connecticut; 50,000 employees displaced for an average duration of 5 days in Rhode Island; 30,000 employees displaced for an average of 3 days in Massachusetts; 155,000 unemployed for a period of less than 1 day in New Hampshire; and 10,000 employees displaced for an average of one and one-half days in Maine.

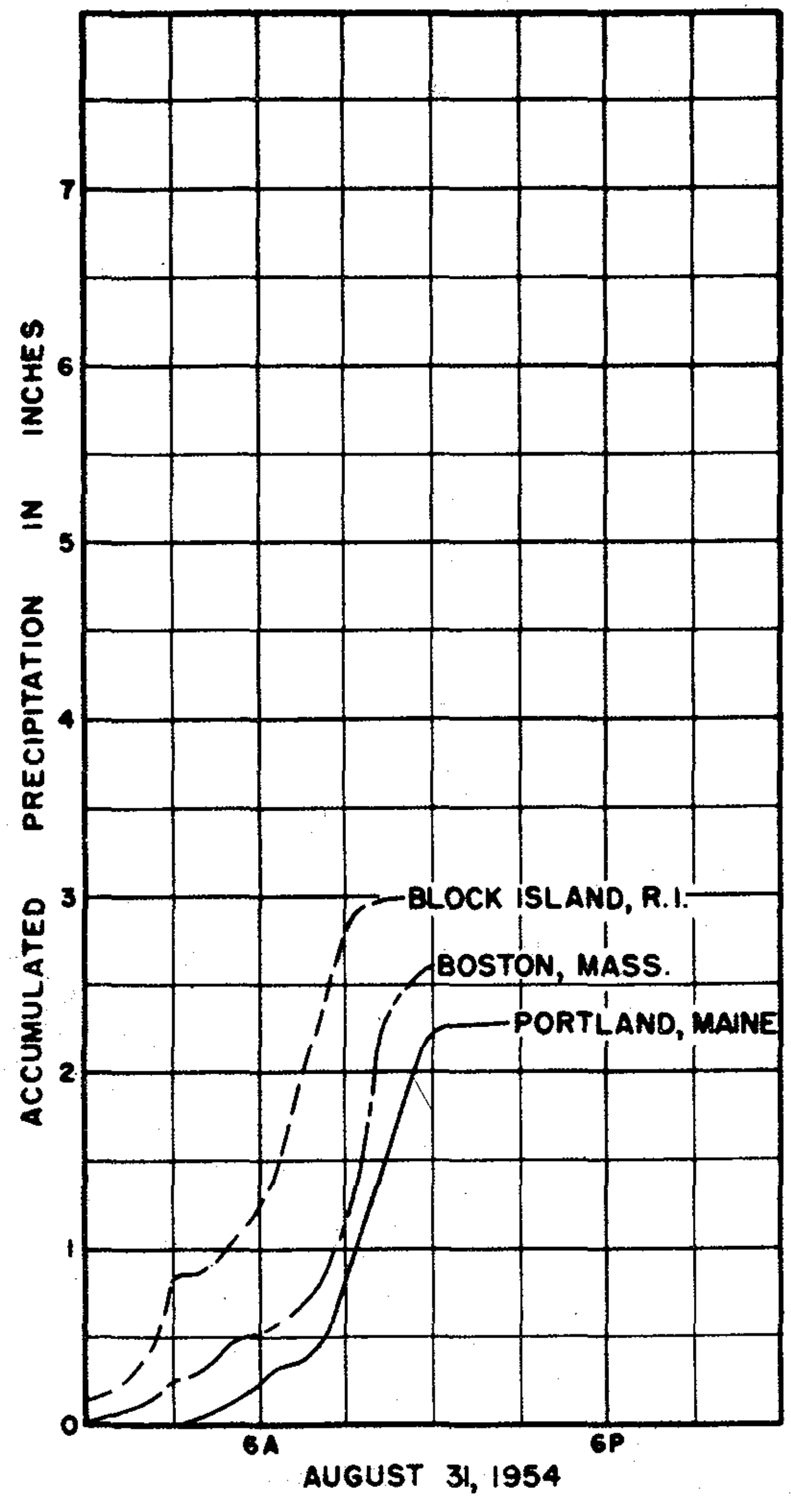
103. <u>Interior river flood damages.</u> - Rainfall accompanying Hurricanes Carol and Edna caused substantial flood damages in New England, with Maine and Massachusetts suffering most heavily. Virtually all such flood damage occurred during and after Hurricane Edna, although the rains of Hurricane Carol had helped to set the stage. Hurricane Carol, passing close to Providence, thence northward approximately between Worcester and Boston, contributed from two to four and one-half inches of rain throughout New England from early morning through afternoon, with the heaviest fall recorded in southern New Hampshire. These rains caused minor to moderate rises in the flow of tributary streams on August 31 and September 1. Resultant damages were minor, but ground water levels were raised. Following Hurricane Carol, local and general rains September 3, 6, 7, 8, and 9 further raised ground water levels to set the stage for Hurricane Edna. Plates 69 and 70 show characteristics of rainfall in Hurricanes Carol and Edna.

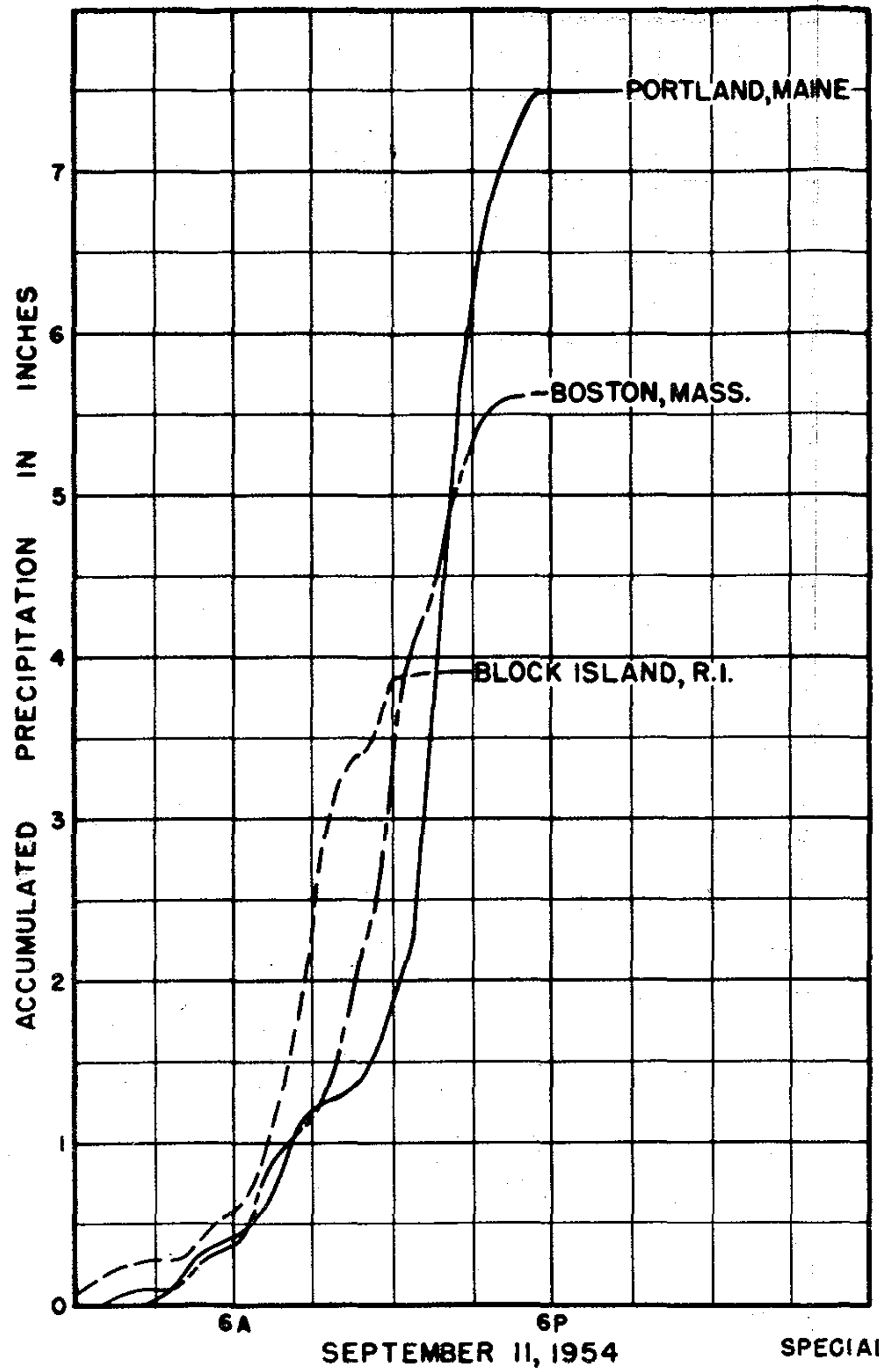
104. Hurricane Hazel caused some minor flooding in the extreme western portion of the region. Rains accompanying Hurricane Edna on September 11, between early morning and early evening averaged about four inches in the six-state area and varied from over eight inches along the eastern coastline between the mouth of the Merrimack and Presumpscot Rivers to less than two inches over Vermont. The total rainfall in Maine was reported the heaviest in 58 years. Sharp rises in streamflow and river stage occurred during the morning of September 11 as the torrential rains poured down upon ground already conditioned for a high rate of run-off. As a consequence, serious flooding followed in many of Maine's Rivers and tributary streams; in the Exeter River and the Merrimack River

Basin in New Hampshire; in the Sudbury, Assabet, Mystic, Malden, and Westfield Rivers in Massachusetts; the Blackstone River in Rhode Island; and the Thames in Connecticut. In addition, many localities in all New England States suffered severely from flooding of low-lying areas, and from the flooding caused when sewer systems already clogged by debris, were incapable of discharging the heavy run-off.

105. No detailed estimates of monetary damage caused by the high run-off of Hurricane Edna are available. A summary of representative flood conditions and accompanying damages in the various New England States, however, will provide a general picture of the extent and seriousness of the effects. A summary by States follows:

a. Maine. - Maine was more seriously damaged by river flooding during Hurricane Edna than any other New England State. All major rivers were swollen and flash flooding occurred on tributary and minor streams. Road and rail washouts, flooded roads, fields and residential areas were common throughout the state. The raging river torrents smashed bridges and caused extensive damage to commercial and industrial properties. Culverts and bridge abutments, many of them built of massive stone in the last century, were broken and washed downstream making highways and railroads impassable. In addition, storm sewers, some inadequate and others blocked by debris, were not capable of carrying off the torrential rains and overflowed. The cellars of thousands of homes were flooded. Eight deaths, all due to drowning, were reported. The following descriptions are representative of the type and extent of damage caused:





SPECIAL SUBJECTS–REGIONAL

MASS RAINFALL CURVES

HURRICANES OF AUG. 31 & SEPT. 11, 1954

(SELECTED STATIONS)

NEW ENGLAND-NEW YORK INTER-AGENCY COMMITTEE

NOV. 1954

ARMY NED BOSTON, NOV. 1954

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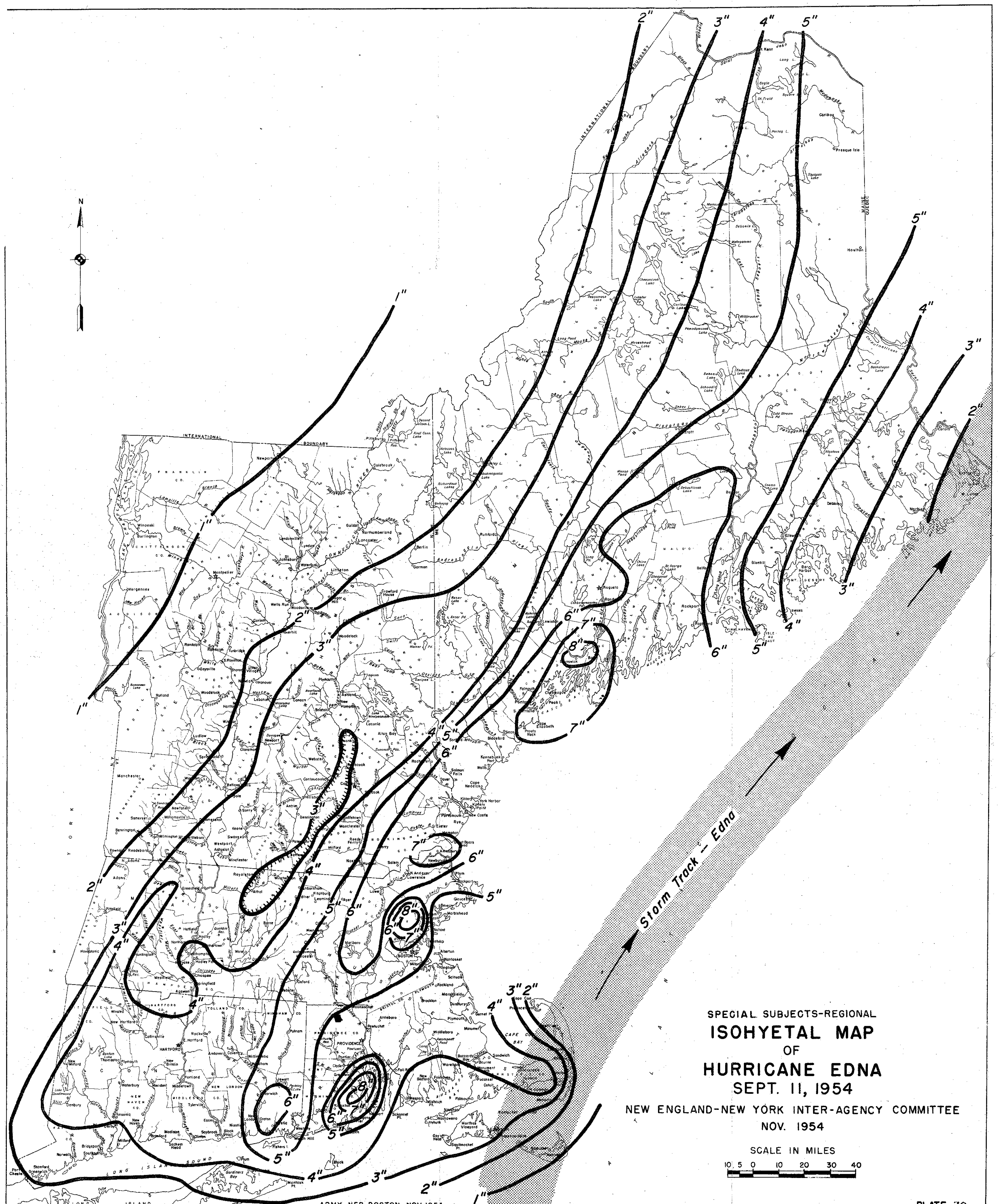

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(1) On the Kennebec River 40,000 cords of pulpwood were carried downstream when booms at Winslow gave way. The river was later closed to navigation while lumber crews completed salvage operations. Crews managed to salvage substantial quantities of pulpwood from as far away as Old Orchard Beach, although a great deal washed out to sea. Sandy Stream, in flood at Unity, caused the loss of three lives. At Skowhegan, the normal flow of 3,500 cubic feet per second jumped to 62,000 c.f.s. on September 12, and the river was reported 20 feet above normal at Augusta. Commercial establishments and homes at Waterville, Augusta, Hallowell, Gardiner, and Richmond were evacuated and valuables moved to upper levels. Large storage reservoirs at Flagstaff Lake and Moosehead Lake were nearly full and consequently were only slightly beneficial in reducing river stages.

(2) In the Androscoggin Basin, the Little Androscoggin River overflowed its banks, closing the Lewiston-Portland road. Tributary streams caused widespread local flooding.

(3) The Penobscot River crested at West Enfield on September 13 at a stage of 15.85, representing a flow of 74,700 c.f.s., or about half the discharge recorded in the flood of May 1, 1923.

(4) The Presumpscot River caused flooding at the Riverton Bridge connecting Portland and Westbrook. Although usually a narrow river at this point, the river flooded meadows a quarter of a mile wide causing thousands of dollars damage to farming equipment. Stock and machinery in an industrial establishment were soaked and silt laden. In Portland, a retaining wall at the Munjoy Hill Reservoir of the Portland Water Dis-

trict was weakened by the pounding rains and the reservoir was drained as a precautionary measure to avoid a repetition of a failure which occurred in 1893.

(5) At York and Old Orchard Beaches, lowlands behind the beaches were flooded because many of the storm sewers were inadequate and because the higher than normal tides backed up into storm sewers having ocean outfalls. The Town of Pownal was virtually isolated as 14 bridges were washed out on main and secondary roads.

b. New Hampshire. - Though less seriously affected than Maine, New Hampshire suffered some flood damage in Hurricane Edna. The most serious damage occurred on the Exeter River and in the upstream tributaries of the Merrimack River Basin. Brief descriptions of general damage in these areas follow.

(1) The flooding Exeter River forced evacuation of 400 persons early in the morning of September 12. Later in the day, the breaching of West Brentwood Dam, 11 miles up river from Exeter, at Kingston, threatened failure of the Pickpocket Dam, just above Exeter. Flood waters affected Linden Street, Ball Avenue, lower Court Street and Crawford Street where the water was three feet deep in first floor apartments. There was minor flooding of the Androscoggin River in the White Mountain Town of Milan.

(2) In the Merrimack River Basin there was flooding on the upstream tributaries. The most serious flooding occurred in the area above Plymouth, New Hampshire, on the Baker and Pemigewasset Rivers, where Routes 25 and 104 were closed and people were evacuated from low

areas. Although peak inflow was 25,000 c.f.s. into Franklin Falls Reservoir, outflow from the reservoir did not exceed 16,000 c.f.s. and during the peak of the downstream flood the outflow was reduced to 10,000 c.f.s. The combined effect of The Franklin Falls and Blackwater Reservoirs kept flows at Concord, New Hampshire below damaging stage. The Edward MacDowell Reservoir was operated to prevent local flooding in the Peterborough area. (See Plates 71, 72, and 73).

(3) Elsewhere in the state, Hurricane Edna caused damage to highways and rail lines. Surry Mountain Reservoir was operated to reduce stages of the Ashuelot River through Keene. The Taylor River overflowed and cut traffic on the New Hampshire Turnpike. (See Plate 74).

c. Vermont. - Flooding caused by the rains of Hurricane Edna in Vermont was minor in character. Some transportation facilities were disrupted due to road washouts and localized flooding. Union Village Reservoir on the Ompompanoosuc River was operated to reduce downstream stages. (See Plate 75).

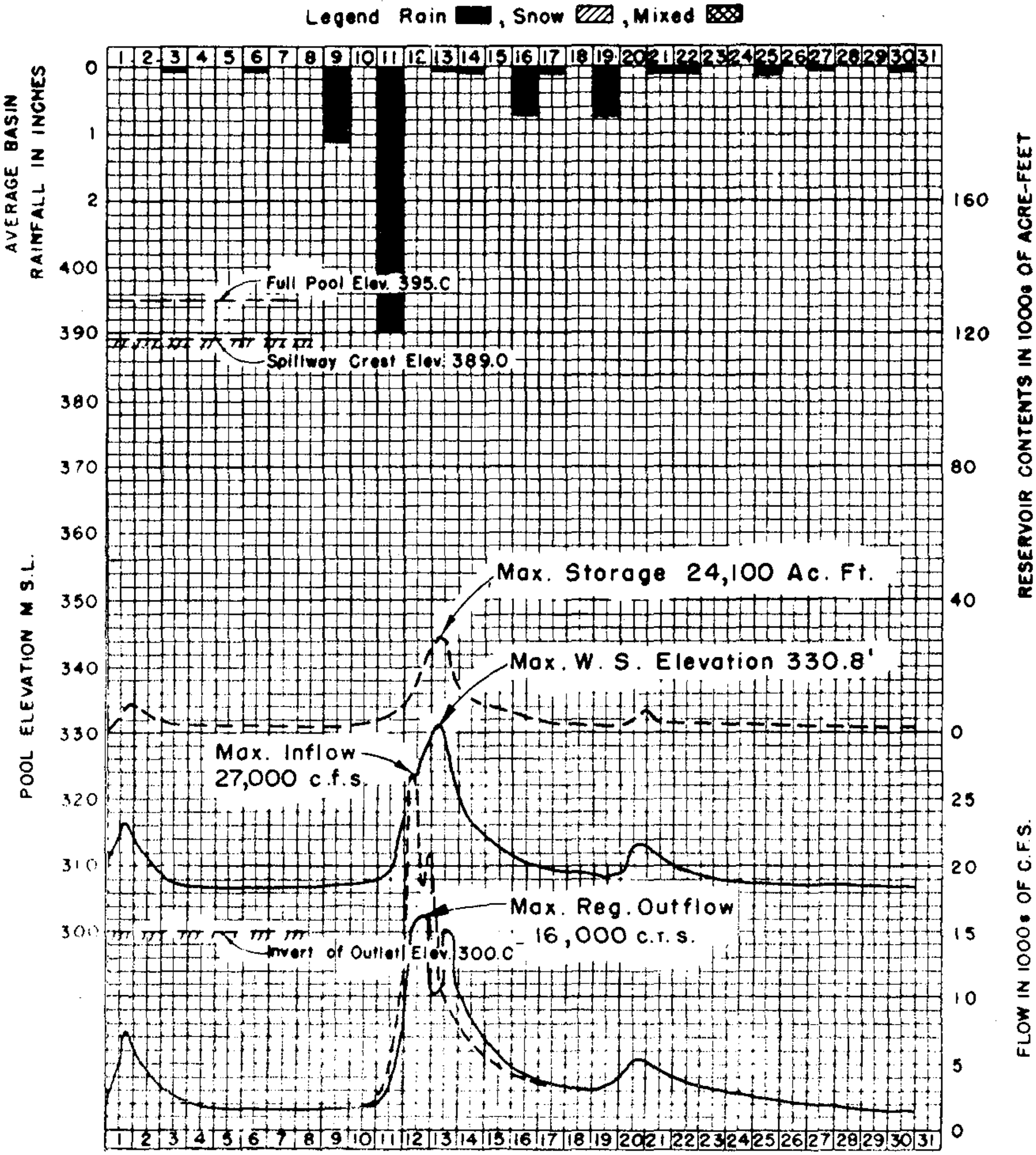
d. Massachusetts. - The rainfall of Hurricane Edna caused millions of dollars of damage to Massachusetts homes, business properties, automobiles and transportation facilities. Flood water run-off built up in low spots where drains were blocked with leaves from fallen trees and other storm debris. Ponds and rivers overflowed their banks bringing damage to places which never before had suffered such damage. Representative damages are described below.

(1) Flooding in the Sudbury and Assabet Rivers, tributaries forming the Concord River, forced some families from their homes

and inundated low-lying fields. The Sudbury River flooded cellars and made some riverbank roads impassable in Framingham, Wayland and Sudbury. In Framingham, where the water level was 15 feet above normal at one point, 50 families were made temporarily homeless and up to 1,000 homes had flooded cellars. Union Avenue and side streets were flooded. Hard hit were the lower-level stores of Shoppers' World, Dennison Manufacturing Company, Hogman Rubber Company and the Roxbury Carpet Company. In the Saxonville section, School Street was under several feet of water. In Wayland, 13 homes in the Lee Road area were cut off when a clogged culvert under the Old Post Road flooded the neighborhood to a depth of about five feet. About 50 Billerica residents were forced to vacate their homes when the Concord River overflowed in the Elsie Avenue and Queensland sections. All told, damages were estimated to be close to $600,000 in the Concord River watershed.

(2) Arlington had trouble from overflow of the Upper Mystic Lakes and the Arlington Reservoir. In the Highlands section, Mill Brook, fed by Arlington Reservoir, flooded the town garage and scores of business establishments and houses in the vicinity of Brattle Street. A 6-foot section of the street was washed away, and six families were evacuated.

(3) In Medford, many houses suffered water damage when the Mystic River went over its banks but greatest losses occurred from overflowing storm drains and brooks. In Malden and Everett, the overflowing of the Malden River flooded cellars. Ispwich had three blocks under water with water three feet deep over the municipal parking lot. Numerous other



PEMIGEWASSET RIVER BASIN

D.A. 1000 SQ. MILES

MONTH OF SEPT. 19 54

	ELEVATION	GROSS STORAGE Ac. Ft.
Pool, Ordinary Flow	3070	3000
Pool at Spillway Crest	3890	154000
Full Pool	3950	170000
Outlet Capacity with Pool at Spillway Crest	42000 c.f.s.	
Maximum Regulated Outlet Discharge	18500 c.f.s.	

SPECIAL SUBJECTS – REGIONAL

MONTHLY RESERVOIR OPERATION

FRANKLIN FALLS RESERVOIR

NEW ENGLAND–NEW YORK INTER-AGENCY COMMITTEE

NOV. 1954

ARMY NED BOSTON, NOV. 1954

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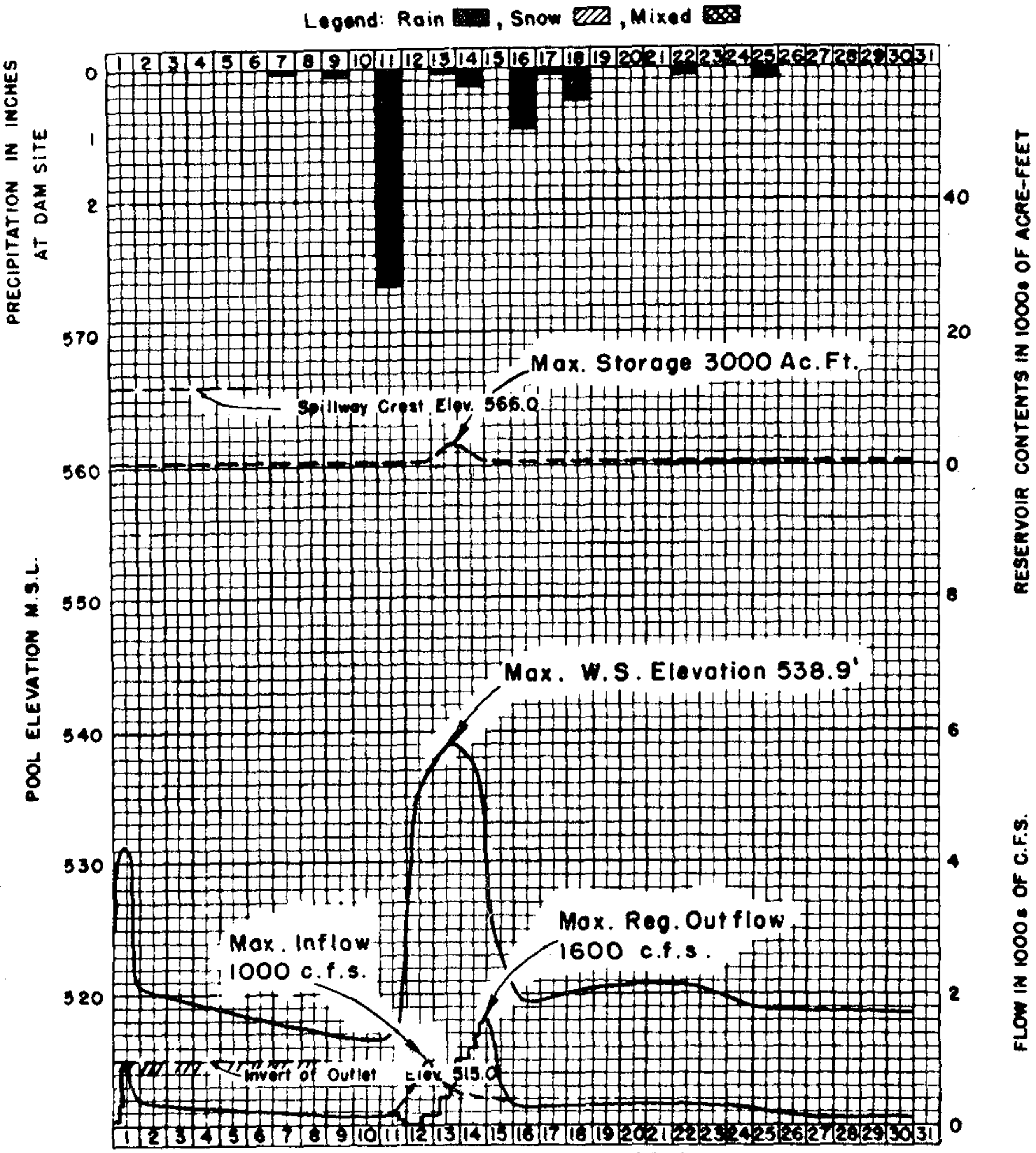


BLACKWATER RIVER BASIN
D.A. 128 SQ. MILES

MONTH OF SEPT. 1954

	ELEVATION	GROSS STORAGE Ac. Ft.
Low Flow Pool	518.±	0
Full Pool	566.0	46,000

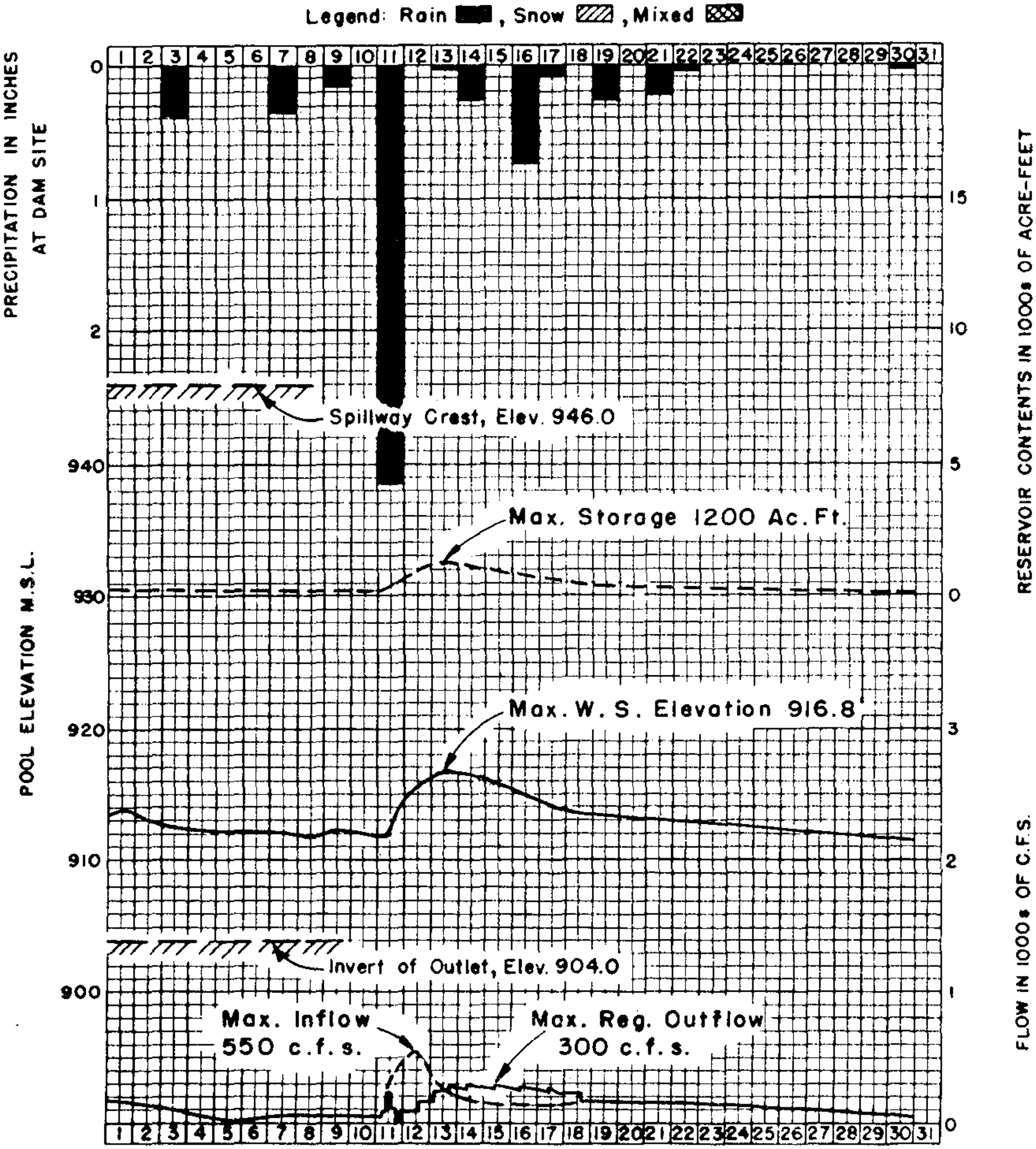
Outlet Capacity at Full Pool 2800 c.f.s.

SPECIAL SUBJECTS-REGIONAL

MONTHLY RESERVOIR OPERATION
BLACKWATER RESERVOIR

NEW ENGLAND-NEW YORK INTER-AGENCY COMMITTEE
NOV. 1954

ARMY NED BOSTON, NOV. 1954



MONTH OF SEPT. 19 54

MERRIMACK RIVER BASIN
D.A. 44 SQ. MILES

ELEVATION

Low Pool	911.2 (Top of downstream flashboards)	
Full Pool	946.0	12,800 Ac. Ft.

Outlet Capacity at Full Pool 1760 c.f.s.

Invert Elevation at Intake 904.0 ft. m.s.l

SPECIAL SUBJECTS-REGIONAL

MONTHLY RESERVOIR OPERATION

EDWARD MAC DOWELL RESERVOIR

NEW ENGLAND-NEW YORK INTER-AGENCY COMMITTEE

NOV. 1954

ARMY NED BOSTON, NOV. 1954

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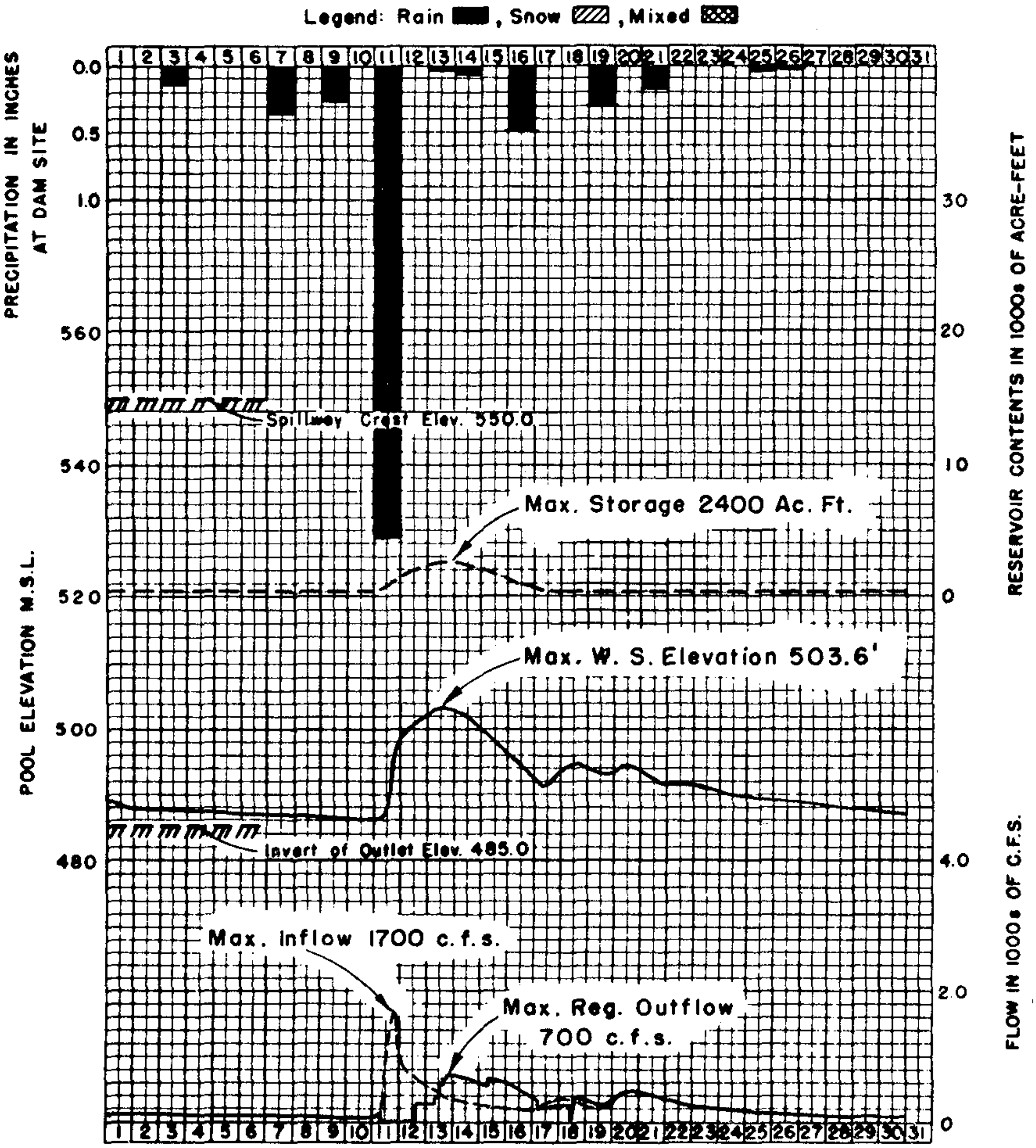


ASHUELOT RIVER BASIN
D.A. 100 SQ. MILES

MONTH OF SEPT 1954

	ELEVATION	GROSS STORAGE Ac. Ft.
Conservation Pool	NONE	
Full Pool	550.0	32500

Outlet Capacity at Full Pool 3660 c.f.s.

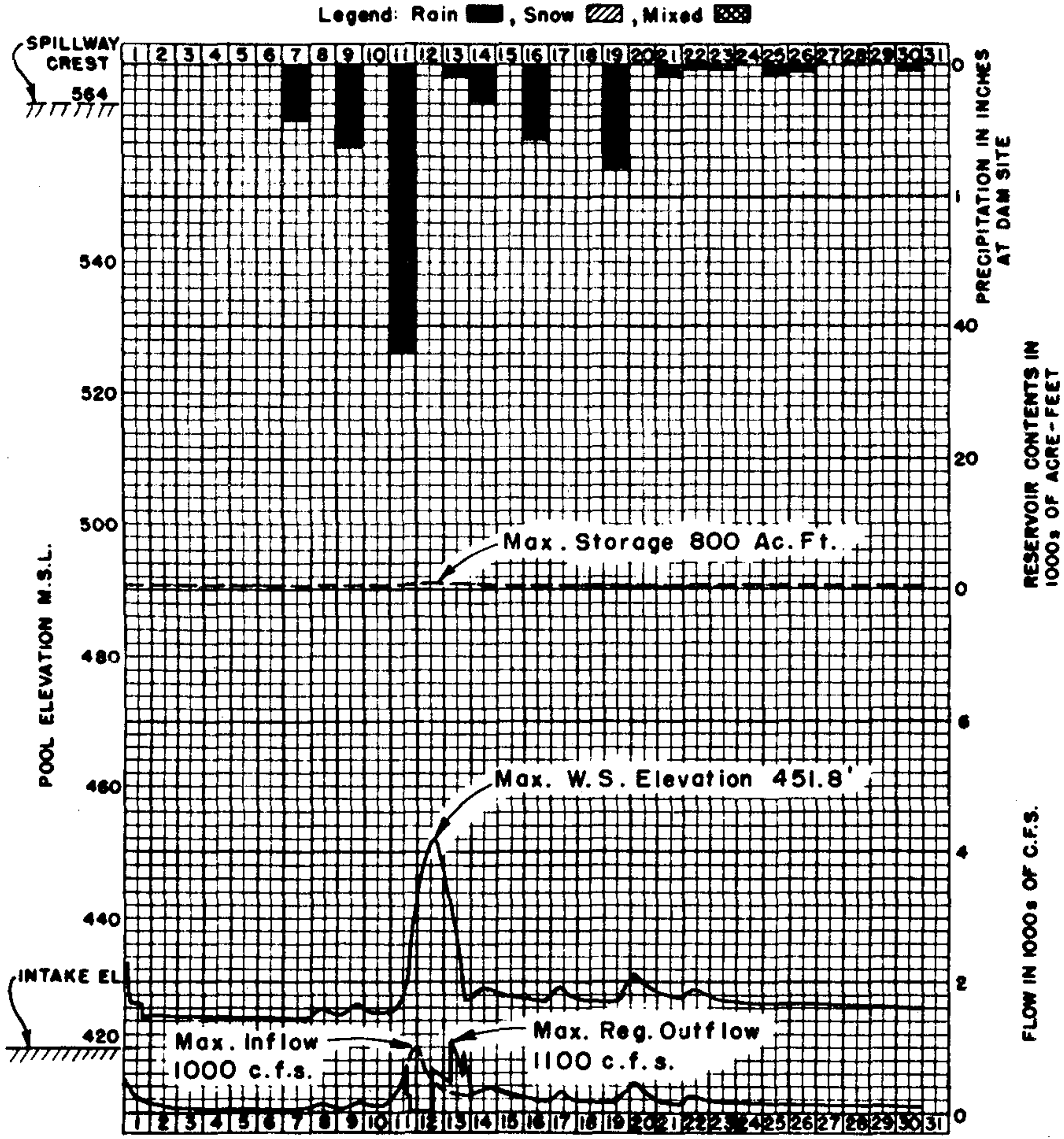
Invert Elevation at Intake 485 ft. m.s.l.

SPECIAL SUBJECTS-REGIONAL

MONTHLY RESERVOIR OPERATION
SURRY MOUNTAIN RESERVOIR

NEW ENGLAND-NEW YORK INTER-AGENCY COMMITTEE
NOV. 1954

ARMY NED BOSTON, NOV. 1954



CONNECTICUT RIVER BASIN
D.A. 126 SQ. MILES

MONTH OF SEPT. 1954

	ELEVATION	GROSS STORAGE Ac. Ft.
Conservation Pool	NONE	
Full Pool	564'	38,000

Outlet Capacity at Full Pool 7800 c.f.s.

Invert Elevation at Intake 420 ft. m.s.l.

SPECIAL SUBJECTS-REGIONAL

MONTHLY RESERVOIR OPERATION

UNION VILLAGE RESERVOIR

NEW ENGLAND-NEW YORK INTER-AGENCY COMMITTEE

NOV. 1954

ARMY NED BOSTON, NOV. 1954

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streets were flooded by heavy rains which caused Farley Brook to overflow its banks. In Boston, cellar flooding was widespread. Heavy run-off collected on Storrow Dirve blocking traffic until restored power permitted pumping. The Worcester Turnpike was impassable in several places, mostly at underpasses.

(4) In the Connecticut River Basin, run-off was insignificant except on the Westfield River, on which there was minor flooding in the lowlands of the Town of Westfield, caused by the local flow from the uncontrolled area below Knightville Dam. During the time the gates at Knightville were completely closed, the stage at the gage in the lower end of Westfield reached 13.1 feet, a reduction in stage of 3.7 feet below the stage of 16.8 feet that would have been reached under natural conditions. The stage where damage begins in the town is about 14.5 feet, or 2.3 feet less than the peak stage would have been, representing damage prevention of about $50,000. Birch Hill and Tully Reservoirs were also operated to lower downstream stages on the Millers River. (See Plates 76, 77, and 78).

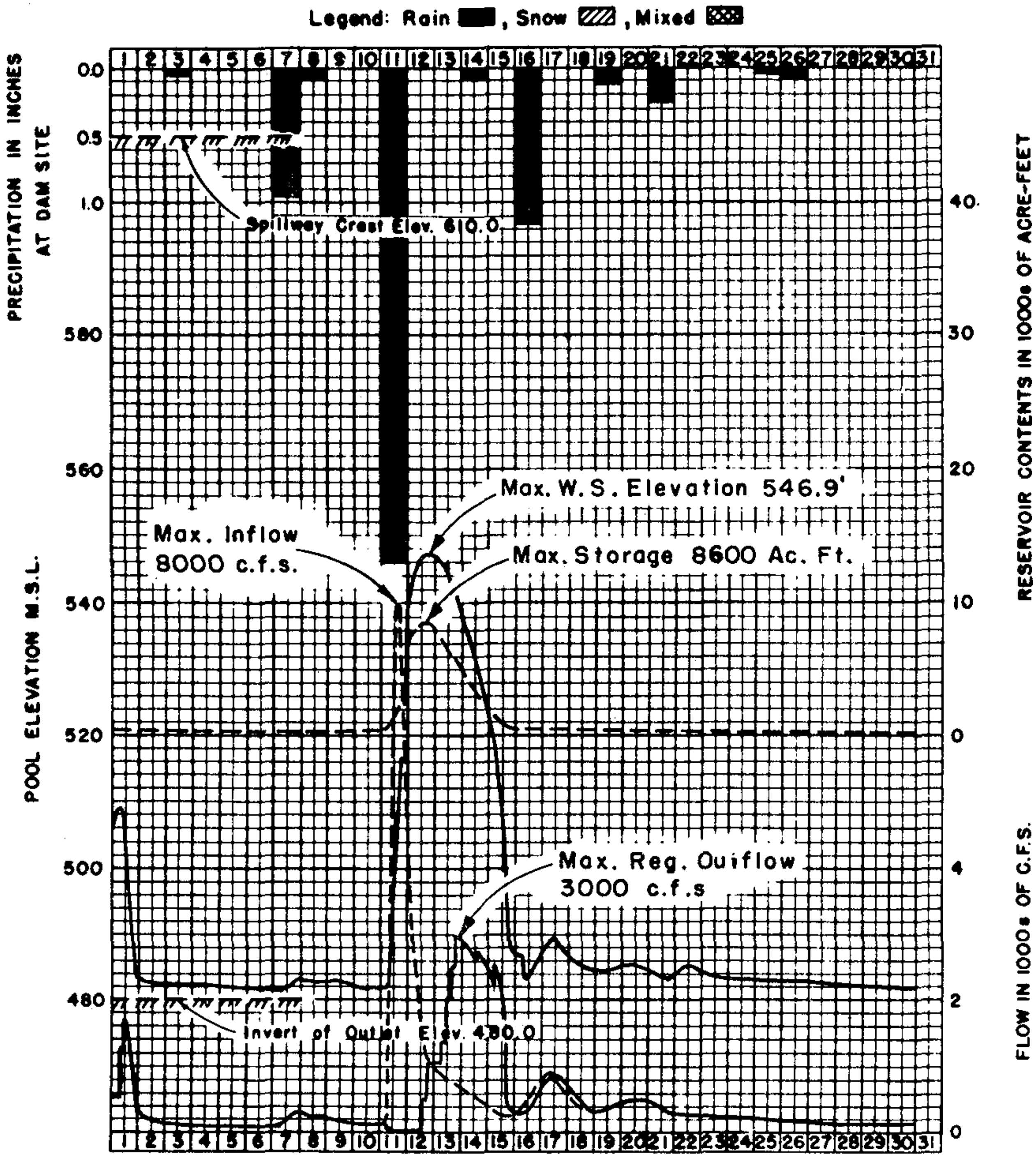
e. Rhode Island. - Rhode Island, though considerably less seriously hit by Hurricane Edna than by Hurricane Carol, suffered its share of flooding in the second storm. Major damage in the state resulted from clogged and inadequate sewer systems and from the overflowing of the Blackstone River. Providence and many other cities and towns found sewer systems unable to take the tremendous downpour of Hurricane Edna. This condition was complicated by leaves and other debris blocking catch basins. Roads were flooded in many low-lying areas but washouts for the most part were minor. The New York, New Haven and Hartford

Railroad had minor washouts which were quickly repaired.

(1) The Blackstone River flooded residential, commercial and industrial properties throughout its length. It reached flood stages during September 12 and caused flooding to basements of mills in Woonsocket. It is estimated that stages at Woonsocket were four to five feet below those occurring during past record floods. Two tributaries, the Peters and Mills Rivers, contributed heavily to flow in the Blackstone which overflowed its banks in the Social District (Social Street) of Woonsocket. The Masurel Worsted Mills and the Woonsocket Plant of the U. S. Rubber Company were forced to close down for two eight-hour shifts. The Harris Pond section had several feet of water flooding the cellars of homes.

f. Connecticut. - In Connecticut, the rains that accompanied Hurricane Edna caused damages paralleling those of Rhode Island and eastern Massachusetts. Major rainfall occurred in the eastern sections of the state and diminished in intensity in a westerly direction. Lowlands, cities and towns were flooded as the downpours piled up on clogged catch basins and restricted culverts.

(1) In the Thames River Basin, the effects of Mansfield Hollow Reservoir reduced the river level six feet in the Natchaug River area, and by two feet in the lower end of the Shetucket River in Norwich, preventing estimated damages of $100,000. The Mansfield Hollow gates were closed during the flood and the reservoir pool reached 31.3 feet, the highest elevation attained since the dam was placed in operation in March 1952. Table 95 summarizes the reservoir regulation at Mansfield



WESTFIELD RIVER BASIN
D.A. 162 SQ. MILES

MONTH OF SEPT. 19 54

	ELEVATION	GROSS STORAGE Ac. Ft.
Conservation Pool	NONE	
Full Pool	610	49,000

Outlet Capacity at Full Pool 15000 c.f.s.

Invert Elevation at Intake 480 ft. m.s.l.

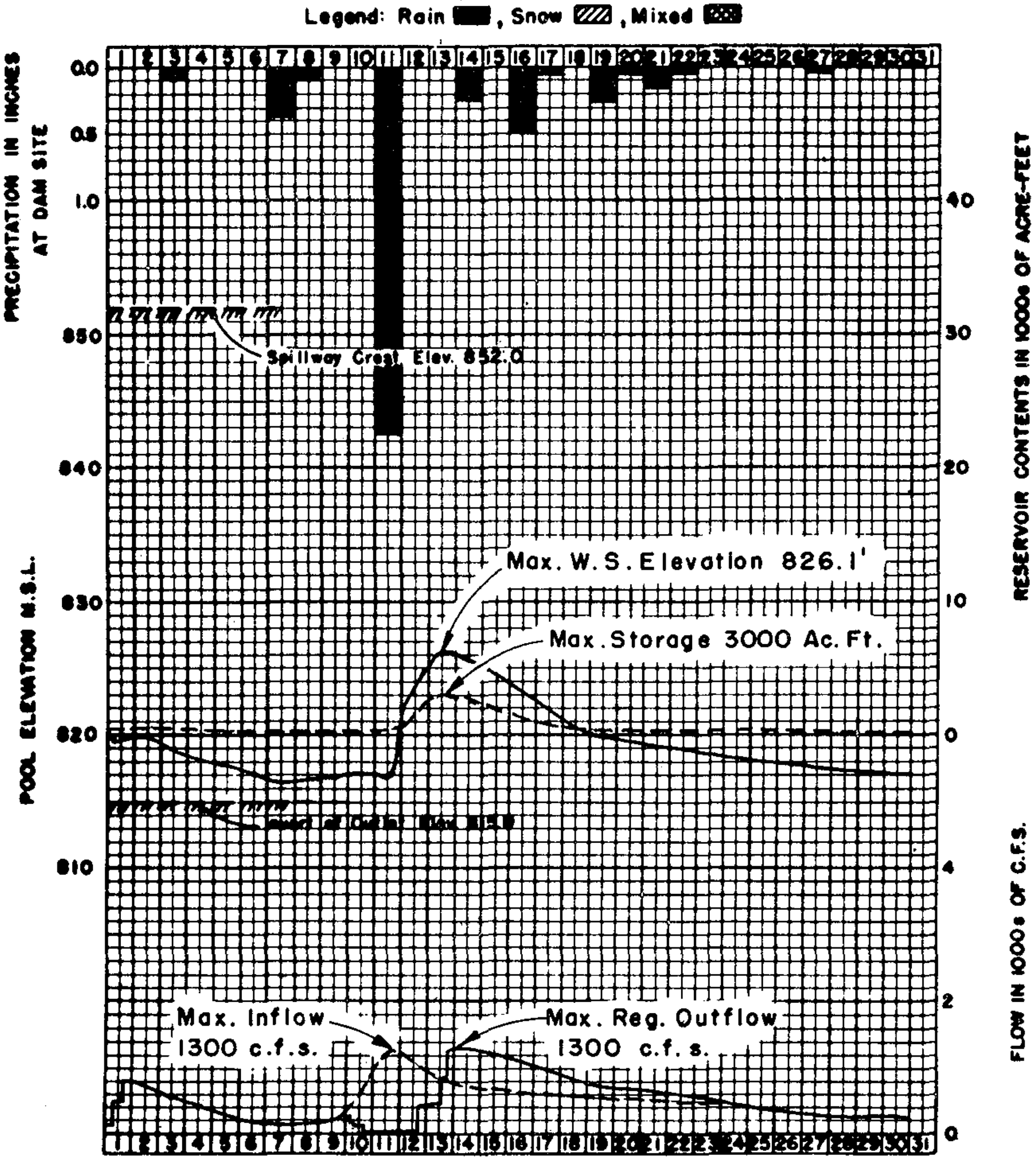
SPECIAL SUBJECTS - REGIONAL

MONTHLY RESERVOIR OPERATION

KNIGHTVILLE RESERVOIR

NEW ENGLAND-NEW YORK INTER-AGENCY COMMITTEE
NOV. 1954

ARMY NED BOSTON, NOV. 1954



MILLERS RIVER BASIN

D.A. 175 SQ. MILES

MONTH OF SEPT. 19 54

	ELEVATION	GROSS STORAGE Ac. Ft.
Conservation Pool	NONE	
Full Pool	852	49,900

Outlet Capacity at Full Pool 10,500 c.f.s.

Invert Elevation at Intake 815 ft. m.s.l.

SPECIAL SUBJECTS–REGIONAL

MONTHLY RESERVOIR OPERATION

BIRCH HILL RESERVOIR

NEW ENGLAND–NEW YORK INTER-AGENCY COMMITTEE

NOV. 1954

ARMY NED BOSTON, NOV. 1954

PLATE 77

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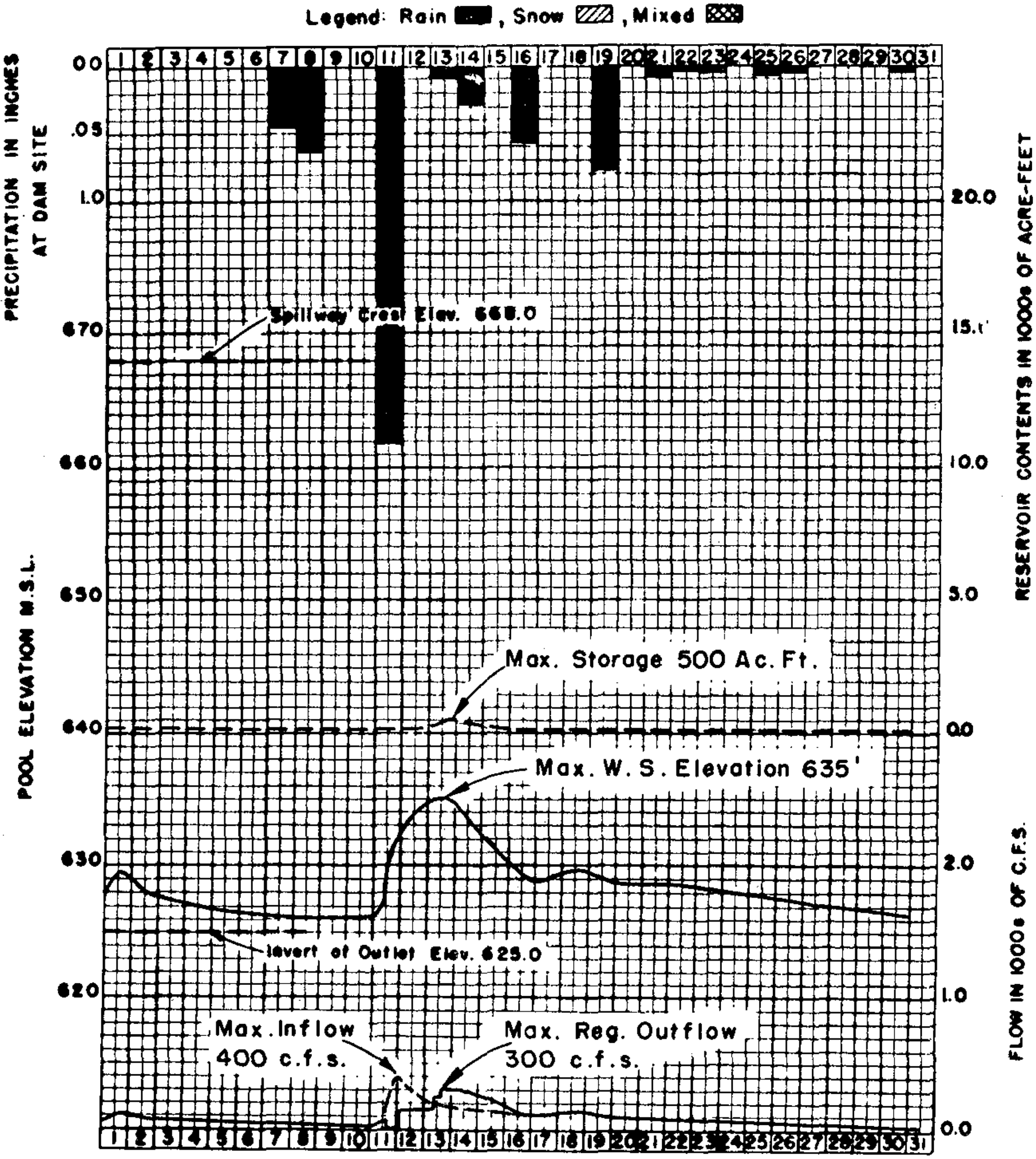


TULLY RIVER BASIN
D.A. 50 SQ. MILES

MONTH OF SEPT. 1954

	ELEVATION	GROSS STORAGE Ac. Ft.
Conservation Pool	None	
Full Pool	668.0	22,000

Outlet Capacity at Full Pool 1,030 c.f.s.

Invert Elevation at Intake 625.0 ft. m.s.l.

SPECIAL SUBJECTS-REGIONAL

MONTHLY RESERVOIR OPERATION

TULLY RESERVOIR

NEW ENGLAND-NEW YORK INTER-AGENCY COMMITTEE

NOV. 1954

ARMY NED BOSTON, NOV. 1954

Table 95 - Summary of reservoir regulation in New England, Hurricane Edna, New England-New York Region

Reservoir	Drainage area sq. mi.	Total precip. inches	Maximum pool stage ft.	Maximum pool date 1954	Computed peak inflow c.f.s.	Regulated outflow minimum regulated c.f.s.	Regulated outflow maximum regulated c.f.s.	Storage used acre feet	Storage used percentage of total
CONNECTICUT RIVER BASIN									
Union Village	126	2.21	31.8	9/12	1,000	0	1,100	800	2
Surry Mountain	100	3.55	18.6	9/13	1.700	0	700	2,400	7
Birch Hill	175	2.75	11.1	9/13	1,300	0	1,300	3,000	6
Tully	50	2.84	10.0	9/13	400	0	300	500	2
Knightville	162	3.70	66.9	9/12	8,000	0	3,000	8,600	18
MERRIMACK RIVER BASIN									
Edward MacDowell	44	3.15	12.8	9/13	550	0	300	1,200	10
Blackwater	128	3.25	23.9	9/13	1,000	0	1,600	3,000	7
Franklin Falls	1,000	3.00	30.8	9/13	27,000	10,000	16,000	24,000	15
THAMES RIVER BASIN									
Mansfield Hollow	159	4.25	31.3	9/13	7,800	0	2,500	12,200	24

Table 96 - Summary of damages by state for 1954 hurricanes, New England - New York Region

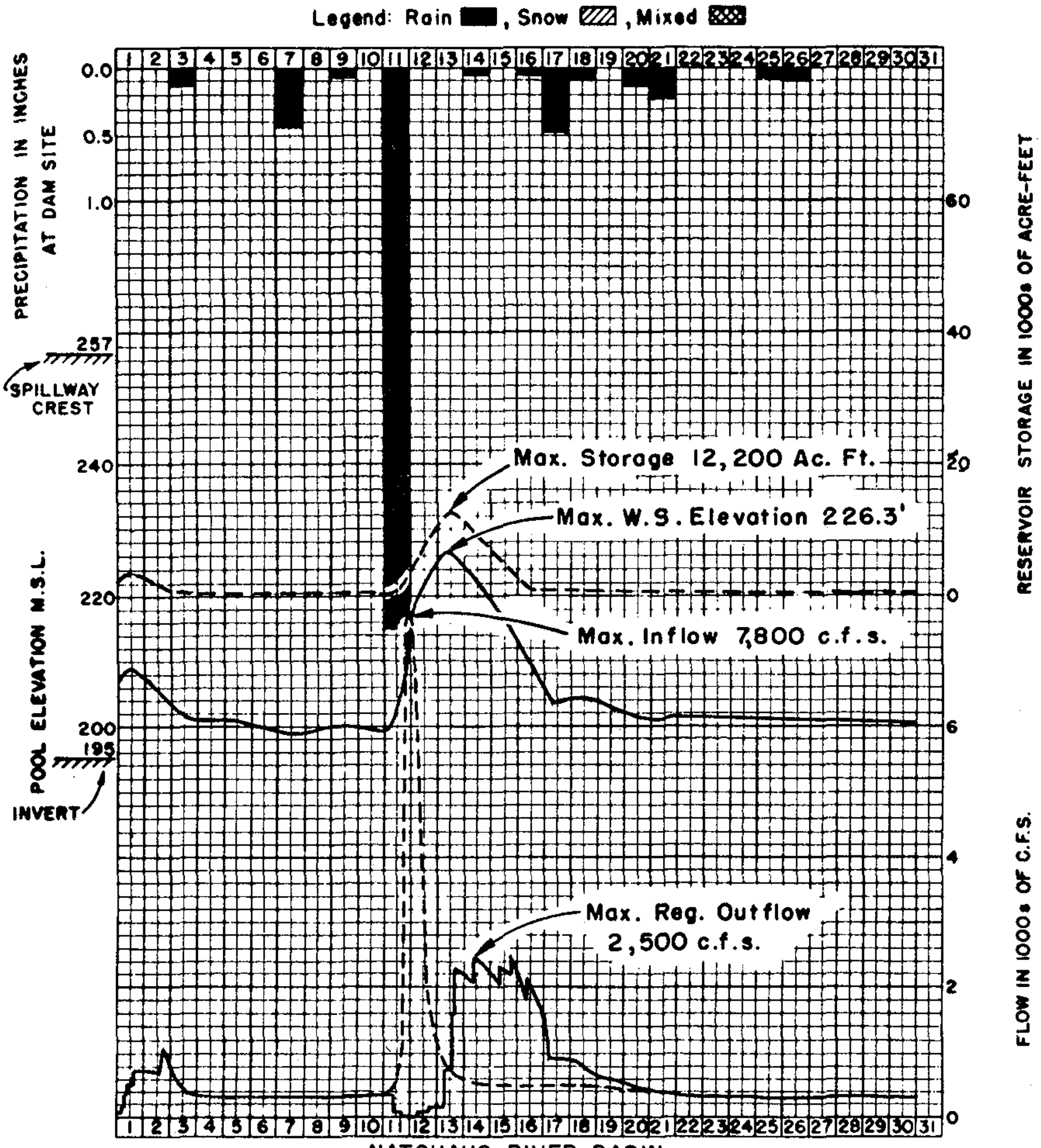
See footnote 1/

State	Hurricane Carol	Hurricane Edna	Hurricane Hazel	Combination 2/ of storms	Total
Connecticut	$ 28,168,750	$ 4,766,000	$ 147,150	$ 3,018,500	$ 36,100,400
Rhode Island	97,965,900	5,672,400		2,742,200	106,380,500
Massachusetts	92,992,900	10,887,100		7,609,000	111,489,000
New Hampshire	4,128,750	1,369,250		2,498,300	7,996,300
Maine	5,675,000	8,756,000		10,000,000	24,431,000
Vermont				100,000	100,000
New York	6,312,500	1,296,000	5,704,200	5,609,000	18,921,700
New England 3/			100,000		100,000
Region 3/				300,000	300,000
Total	$235,243,800	$32,746,750	$5,951,350	$31,877,000	$305,818,900

1/ Incomplete estimates for damage in interior areas.

2/ Information furnished not separable by storm.

3/ Information not separable by state.



NATCHAUG RIVER BASIN
D.A. 159 SQ. MILES

MONTH OF SEPT 19 54

	ELEVATION	GROSS STORAGE Ac. Ft.
Conservation Pool	NONE	
Full Pool	257.0	52,000

Outlet Capacity at Full Pool 10,200 c.f.s.

Invert Elevation at Intake 195.0 ft. m.s.l.

SPECIAL SUBJECTS-REGIONAL

MONTHLY RESERVOIR OPERATION

MANSFIELD HOLLOW RESERVOIR

NEW ENGLAND-NEW YORK INTER-AGENCY COMMITTEE

NOV. 1954

ARMY NED BOSTON, NOV. 1954

Hollow and the other flood control structures operated by the New England Division, Corps of Engineers. (See Plate 79).

106. <u>Summary</u>. - The total hurricane damages in the region, as given in preceding paragraphs, are summarized by state and by storm in Table 96. Estimates of damage for interior areas are incomplete. Table 97 gives a summary of these damages by type of loss.

Table 97 - Summary of 1954 hurricane damages by type of loss, New England-New York Region

Type	Loss
Public property	$ 53,822,200
Shipping	12,881,000
Utilities	39,193,900
Transportation	2,800,000
Commercial	55,167,500
Industrial	38,074,500
Agricultural	29,285,100
Foods and Drugs	7,278,800
Fisheries	3,786,900
Private property	59,670,000
Other 1/	3,859,000
Total	$305,818,900

1/ Inseparable combinations of two or more types of loss.

107. Several coastal communities suffered extensive damage from Hurricanes Carol and Edna but particularly from Hurricane Carol. Table 98 lists losses for seven New England communities resulting from Hurricanes Carol and Edna.

Table 98 - Damage suffered in seven communities in southern New England from Hurricanes Carol and Edna, New England-New York Region

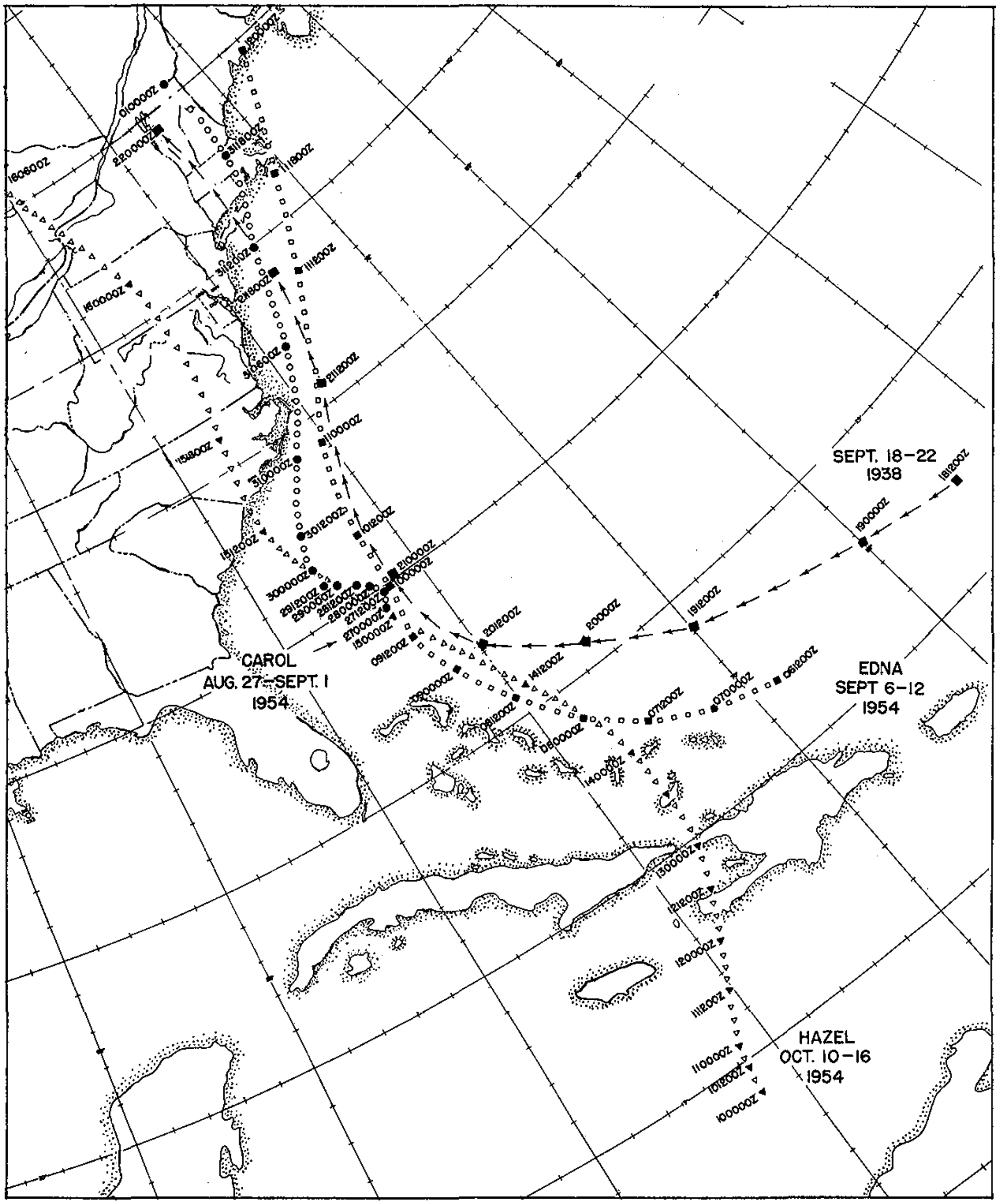
Community	Carol	Edna	Total
Fairfield, Conn.	$ 577,000	--	$ 577,000
New London, Conn.	2,066,000	$ 843,000	2,909,000
Newport, R. I.	2,670,000	121,000	2,791,000
Bristol, R. I.	2,945,000	237,000	3,182,000
Providence, R. I.	51,690,000	1,035,000	52,725,000
Assonet, Mass.	508,000	16,000	524,000
New Bedford, Mass.	15,220,000	1,130,000	16,350,000

The above community estimates are exclusive of any damage to State facilities, military installations, communications and power, that may have been incurred in these communities. Estimates for these excepted items did not permit segregation by locality.

COMPARISON OF 1938 AND 1954 HURRICANES AND EFFECTS

108. The surface and upper air conditions which existed over eastern United States and the western Atlantic areas while the hurricanes were moving northward along the coast were all very similar but the evolution of these conditions was somewhat different in each case. The progress of the three 1954 Hurricanes, Carol, Edna and Hazel and the 1938 (New England) hurricane is shown on Plate 80.

109. The 1938 hurricane moved quite rapidly throughout its entire history, moving around the periphery of a well developed high pressure cell located in the Atlantic Ocean. A very slow-moving, large-amplitude trough of low pressure aloft existed to



SPECIAL SUBJECTS-REGIONAL

PROGRESS OF 1938 AND 1954 HURRICANES

(GREENWICH TIME)

NEW ENGLAND-NEW YORK INTER-AGENCY COMMITTEE

JANUARY 1955

U.S.W.B., BOSTON JAN. 1955

PLATE 80

CHAPTER XXXIX

the west of the Appalachians early in the development of the hurricane when it was still moving almost due westward and located 400 miles north of San Juan, Puerto Rico. This was four days prior to its striking the New England coast. The combination of the deep trough over eastern United States and the high cell in the Atlantic provided a deep and broad band of southerly winds along the eastern seaboard. Since these features remained essentially stationary, this band of winds provided a good steering current for the hurricane. The storm showed little of the normal tendency for deceleration in the recurvature stage and its northward acceleration was marked as it crossed the latitude of 35° N. The increasing forward speed of this hurricane, as well as speeds of the three 1954 hurricanes, is shown in Table 99.

Table 99 - Forward speeds of 1938 and 1954 hurricanes, New England-New York Region

Hurricane	Latitude of observation							
	30°N	32°N	34°W	36°N	38°N	40°N	42°N	44°N
	Forward speed in miles per hour							
1938	18	27	37	40	47	55	62	62
Carol 1954	3	5	18	38	38	33	31	30
Edna 1954	9	15	21	30	32	34	42	45
Hazel 1954	10	14	30	45	55	61	58	53

110. Hurricane Carol developed about 400 miles east of Miami under dissimilar circumstances. It was embedded in an

area of very weak flow aloft, which accounted for its exceedingly slow movement for the first four days of its existence. In addition, several high pressure areas moved eastward off of the New England coast during this period, which also blocked any northward motion of the hurricane. The flow aloft over eastern United States was mainly from west to east for the first day or two after Carol formed. During the period from August 27 to 30 a gradual intensification of a trough aloft developed over Ohio and extended southward into the Gulf of Mexico. This trough line remained almost stationary so that as its amplitude increased a band of southerly winds gradually increased in speed, depth and width, establishing a steering current over the hurricane which finally accelerated it toward New England.

111. The map patterns associated with Hurricanes Edna and Hazel also showed a large-amplitude, deepening trough over the eastern sections of the country and a building ridge line over the Canadian Maritime Provinces which provided southerly steering currents for these storms. The development of the trough associated with Hazel was similar to that of Hurricane Carol but the development occurred further west, which steered this hurricane further west and on an inland track. The trough associated with Hurricane Edna was more like that of the 1938 hurricane, as it was already present over western United States when Edna was passing

about 200 miles north of Haiti. This trough aloft was moving eastward faster than any of those associated with the other three hurricanes but deepened and decelerated over the eastern part of the country. The faster eastward motion of this trough steered Edna on a track further to the east than the other storms.

112. This discussion has pointed out the similarity of the synoptic patterns occurring with these hurricanes. The pattern is a deep and broad flow of southerly winds along the eastern seaboard created by a deep and large-amplitude trough over eastern United States and a correspondingly well-developed ridge line or high center over the western Atlantic at a longitude of about 60° West. Experience with the 1954 storms indicates that the mechanism for developing the required southerly wind steering flow can be foreseen one to two days in advance. The forecast problem becomes one of anticipating the rate at which this current will develop and the extent to which it will influence the hurricane's motion. Research should therefore be directed toward the timing of these developments and upon the rate at which the storm reacts to changes in the steering current.

113. A review of the 30-hour prognostic charts showed that reasonably accurate tracks were forecast but that considerable errors in forward speed were made. These errors all stemmed from a failure to forecast the rapid increases in speed of the hurricanes

as they moved northward along the coast, so that timing of the acceleration of the forward speed of the storms for periods of about 24 hours in advance should be a specific research problem for immediate study.

MENACE TO PUBLIC HEALTH

114. Contamination of food and drugs. - Damages to food and drugs caused by hurricanes create a menace to the public health that may take any or all of three forms: contamination of food and drugs by sewage from polluted flood waters; spoilage of foodstuffs by contamination or lack of refrigeration; and rodent and insect infestations encouraged by accumulations of insanitary garbage or rubbish. Flood waters, particularly in populated areas, must always be considered as polluted and containing pathogenic organisms of the type causing typhoid, gastro-intestinal disturbances and other waterborne diseases.

115. Consumption of contaminated foods and drugs or contact with contaminated buildings and equipment could result in outbreaks of the enteric and other diseases. Spoilage of food may occur following a hurricane because of contamination by polluted flood water and because of lack of refrigeration caused by power failure. Meats, fish and other perishable foods decompose rapidly unless held under proper refrigeration and the ingestion of such decomposed foods could cause food poisoning. Accumulations of insanitary garbage and rubbish caused by contamination of foods and breakdowns in collection systems could result in serious infestations of insects and rodents which could result in transmission of disease by these vectors. Another possible menace resulting from the contamination of foods and drugs and the accumulation of garbage and insanitary rubbish can be caused by the scavenging of these materials by individuals for sale or personal consumption.

116. Following both the hurricanes of September 21, 1938, and August 31, 1954 (Carol) damages to food and drug establishments, including buildings, stocks, and equipment, by contamination with sewage-polluted waters and from power failures, created a serious health menace. The menace was greatest in the more populous areas, particularly those fronting tidal waters. However, prompt action in these areas by local, State and Federal public health and food and drug officials effectively controlled the situation. These agencies inspected and quarantined food and drug establishments and required the disinfection of buildings and equipment; supervised the segregation of undamaged goods from those that had been contaminated by polluted water or spoiled from lack of refrigeration; impounded contaminated and spoiled foods and drugs and monitored the disposal of unsalvable goods, the operation for the salvage of goods for resale, the denaturing or decharacterization of foods for non-human use and the return of goods to manufacturers for re-processing; restricted affected areas and destroyed damaged goods at the places of disposal to prevent scavenging; and directed operations for the disposal of garbage and insanitary rubbish. No cases of disease attributable to foods and drugs damaged by hurricanes were reported for either the 1938 Hurricane or Hurricane Carol.

117. Very little data are available on the cost of correcting the menace to public health from damage to foods and drugs caused by the 1938 hurricane or by Hurricane Carol. However, in the city of

Providence, Rhode Island, the cost of disposing of foods and drugs damaged by Hurricane Carol was reported to be approximately $33,400. The total cost of correcting the public health menace after each hurricane, including labor, equipment and supplies for decontamination, salvage and disposal operations and loss of business income, probably amounted to several hundred thousand dollars.

118. Damages to food and drugs caused by the hurricane of September 14-15, 1944, and Hurricanes Edna and Hazel were negligible as was the menace to public health from these commodities.

119. Contamination of water supplies. - Hurricanes may cause damages to water supply systems creating a menace to public health in a number of ways. Water supply wells and reservoirs may become contaminated by polluted water from floods or high run-offs. Distribution systems may become contaminated by polluted water through breaks in mains; by deliberate filling with polluted water as a precautionary measure against the possibility of fire, following failure of the regular supply; through cross-connections or leaks following loss of pressure through power failure; and by interruption of chlorination due to power failure or lack of pressure. Another menace created by complete failure of a regular supply is the possibility of consumers resorting to the use of other sources of supply which may be unsafe.

120. Records on the menace to public health from contamination of water supplies caused by the hurricane of September 21, 1938 are not complete. The Massachusetts State Department of Public Health

reports that 33 supplies were contaminated when polluted waters flooded well fields or when debris washed from watersheds into reservoirs. Fourteen sources of supply were flooded out and 10 water systems experienced power failures. In Connecticut an unrecorded but considerable number of water supplies were affected by power failure, interruption of chlorination, loss of pressure and contamination. Three water supply systems in Rhode Island were reported contaminated, two by polluted salt water pumped into the systems. There are no records for New Hampshire, but it is known that a number of wells and reservoirs were flooded. Vermont, Maine, and New York have no records indicating that water supplies were contaminated during the 1938 hurricane.

121. None of the States in the region report any menance to water supplies resulting from the hurricane of September 1944. Only three communities reported that water supplies were contaminated or subject to contamination as a result of Hurricane Carol. Narragansett and Wakefield, Rhode Island, reported that ruptured water mains were exposed to contaminated tidal water, and at Lancaster, New Hampshire, a loss in pressure caused the water-actuated chlorinator to fail. No communities in Massachusetts, New York, Connecticut, Maine or Vermont reported any menace to public health from contamination of water supplies.

122. Three communities in Massachusetts reported contamination of water supplies as a result of Hurricane Edna. At Bedford the well field and pumping station were flooded with river water; at Chicopee, a power

failure stopped the operation of the power-operated chlorinator; and at Oxford, the pumping station and well were flooded after failure of an upstream dam.

123. In all the instances above, prompt action by water works and public health officials prior to, during and after hurricanes reduced the menace to public health from contamination of water supplies to a minimum. Orders and instructions to boil water were issued by radio, newspaper and hand bills; emergency chlorination and pumping equipment was installed where most needed. Repairs to chlorinators, pumps and other equipment were made and, in many instances, normal operation restored in a matter of hours. Broken mains were replaced; contaminated wells and distribution systems were disinfected. Frequent bacteriological examinations were made until the safety of supplies had been established.

124. No diseases attributable to contamination of water supplies by the hurricanes of 1938, 1944, and 1954 have been reported. The costs of controlling and correcting these menaces have not been determined or estimated in most instances. The Massachusetts Department of Public Health estimates that the cost to the communities having water supplies contaminated during Hurricane Edna probably did not exceed $4,000. The cost to the three communities affected during Hurricane Carol was probably no greater. The number of communities affected by contaminated water supplies during the hurricane of 1938 was probably well over one hundred and the costs of controlling and correcting this public health menace, including such costs as extra

labor, purchase or rental of emergency equipment, disinfectants, and printing, probably did not exceed $200,000.

125. None of the communities in the region reported contamination of water supplies attributable to Hurricane Hazel.

126. Spoilage of foods. - It is believed that there was little food spoilage caused by the hurricane of September 14-15, 1944, and it is known that spoilage was negligible after Hurricane Edna and Hazel. There was a large spoilage of food resulting from the hurricane of September 21, 1938, and Hurricane Carol. Spoilage was probably greater during the latter because of the growth of the frozen food and home freezer industries. Prompt disposal of spoiled foods from establishments, prevention of scavenging, warnings issued, and the awareness of the average householder to the dangers from spoiled foods reduced this public health menace to a minimum. No cases of food poisoning due to spoilage were reported following either the hurricane of 1938 or Hurricane Carol.

127. Disruption of sanitary sewer systems. - The disruption of sanitary sewer systems caused by hurricanes may create a menace to the public health by polluting waters that may contaminate private homes, business establishments, foods, drugs, water supply wells, reservoirs, pumping stations and treatment plants; and bathing and shellfish areas.

128. The only menace to public health from disruptions of sewerage systems caused by hurricanes were reported by the State health departments of Massachusetts and Rhode Island following

Hurricane Carol. On disruption of the treatment plants at Providence and East Providence, emergency chlorination was substituted to reduce the menace to the public health from the discharge of larger volumes of raw sewage in a highly-populated, flooded area. This emergency measure cost an estimated total of $2,000. Disruption of other sewerage systems in Rhode Island resulted in the closure of a total of 11,000 acres of shellfish area for periods of from three to five weeks. Disruption of the pumping station at New Bedford, Massachusetts, by flooding caused the overflow of raw sewage into an area where shellfish could legally be taken and the area had to be closed to this use.

129. Interference with hospitalization. - There are no records which show that interference with hospitalization resulted from the hurricanes of September 21, 1938, and September 14-15, 1944. It seems certain, however, that there must have been some interference with hospitalization in 1938 due to the severity of flood conditions and the widespread and prolonged power failures. Some records are available for the hurricanes of 1954. Only Hurricane Carol was reported as interfering with hospitalization, and this due to power failures in Rhode Island and Massachusetts.

130. The Veterans' Hospital at Providence experienced a power failure. Power had to be supplied by two auxiliary generators furnished by Civil Defense authorities. Ten other generators were supplied to hospitals in Rhode Island as standby units. In Massachusetts, power failures occurred at hospitals in Arlington and

Stoneham. Civil Defense authorities issued a total of three generators to these institutions. Twenty other generators were issued to public service institutions, some of which may have been assigned to hospitals for standby purposes. The Malden Hospital lost both its regular and emergency sources of power and what might have been a serious situation was averted by running emergency lines from the local Civil Defense headquarters to the hospital. Interference with hospitalization would undoubtedly have been more serious had not special effort been made to restore power quickly to affected hospitals. Also many of the hospitals, particularly the larger ones, had already been provided with auxiliary equipment to meet such emergencies.

RELATION TO NATIONAL DEFENSE

131. Any natural catastrophe has potentially serious repercussions upon national defense. Hurricanes, with accompanying high winds, extreme tides, and copious rainfalls, have damaging but in no way crippling effects. The potential effects may be regarded as primary, those resulting from damage to equipment, and possible isolation and immobilization; and secondary, those resulting from damages to industrial productivity, and the dangers of civil commotion which may accompany or follow a natural catastrophe. None of these potential effects was experienced to a serious degree in the 1954 hurricanes.

132. Hurricanes inevitably cause considerable destruction of defense equipment, particularly at coastal installations where inundation occurs. Docks, boat houses and launchways generally receive severe damage. All types of unprotected equipment at shipyards and repair shops are flooded by the extremely high tides, with some consequent delay in the use of docking and repair facilities. Beacons, buoys, and lighthouses frequently require repairs or replacement. Unless naval vessels are readied and aircraft dispersed beyond the danger areas, highly serious damage can result. The potential damages to inland installations are those caused by wind and torrential rains with consequent damage to buildings, any unprotected equipment, and such facilities as runways and roads.

133. Possible isolation and immobilization result from the necessity of dispersing planes and vessels to other areas, from the

general damage to roads and bridges, and from the interruption of power and telephone facilities. Since the disruptive effects of hurricanes are of short duration, craft can be quickly returned to their bases. Most modern units are suitably equipped to move with reasonable speed to any locality even with highways blocked and bridges destroyed. Since military establishments use radio communications extensively and can supply their most pressing needs for electrical power through the operation of standby and mobile generating equipment, they are in part protected from isolation by power and telephone failure. It is probable, however, that activities connected with Civil Defense are more or less seriously hampered by such failures.

134. In a state of national emergency, the effects of a hurricane upon industrial productivity could be serious, particularly if plants producing critically needed materials sustain serious damage. In the 1954 hurricanes, in fact, industrial plants showed considerable resilience, and remarkable power of recovery from the damaging effects of wind, tidal flooding, and loss of power. Many of the plants which did not suffer power interruption, returned to production immediately following the storm, and others were ready for normal operation as soon as power was restored. Extended interruption of production was the exception. Considering the number of plants in the region and their diversified location, the effect of the hurricanes upon this aspect of national defense must be considered minor.

135. The possible civil commotion immediately prior to, during,

and following a hurricane could be of serious consequence to national defense. However, careful warning of the population, evacuation of persons from threatened areas prior to the striking of a storm, and the maintenance of order after a storm would prevent any serious dangers. Following the Hurricane Carol, civil authorities in Rhode Island and Massachusetts found it desirable to request the National Guard to assist in the enforcement of law and order for the protection of life and property and to insure early recovery. The precise effects of such action upon national defense are difficult to estimate, but it seems probable that danger is minimized when maximum precautions to maintain order are taken in areas of extensive damage.

136. Undoubtedly civil commotion during Hurricane Edna was reduced by the operation of the Weather Bureau Hurricane Advisory Service, the awareness of people living in the area, and the early evacuation of inhabitants of threatened sections. It seems probable that the maintenance of wholly adequate warning systems, the orderly evacuation of persons in endangered areas, and the presence of personnel trained and authorized to maintain order after the storm are the most vital factors in preventing interference with national defense. It is possible that consideration should be given to greater use of Civilian Defense personnel in connection with such work in future storms. Such a procedure would provide an additional source of manpower for the maintenance of order, and would at the same time have the advantage of providing training for the personnel involved. It is to be noted that Civilian Defense personnel performed many important and valuable civic duties during and immediately following the 1954 hurricanes.

CIVIL DEFENSE FUNCTIONS

137. Civil Defense organizations, although primarily established for war-caused disasters, Federally and in some States are authorized to engage in emergency activities in times of natural disasters, including those occasioned by hurricanes. In Federal Civil Defense Administration Region I basic civil defense legislation provides such authority in Maine, New Hampshire, Massachusetts, Rhode Island, Connecticut and New Jersey. In New York such authority is provided for the State organizational level by instructions from the Governor. Appropriate legislation is expected to be re-introduced at the next legislative sessions (1955) in Vermont and New York. Many communities which have been struck by hurricanes or other natural disasters have found that their normal protection services were inadequate to cope with the situation. There have been numerous instances when reinforcements quickly provided could have saved lives and reduced damage. The various Civil Defense Coordinators have the authority to utilize their organizations in such cases. These organizations are a valuable supplementary force which can function independently or in conjunction with other similar forces in the protection of lives and property.

138. The function and value of Civil Defense organizations was demonstrated in the 1954 hurricanes. Where appropriate authority existed at the Federal, State and local levels, these organizations

directed, coordinated and assisted in such activities as:

a. Compiling and disseminating information.

b. Evacuation of coastal areas.

c. Providing emergency shelter, food, and medical care, in cooperation with the American Red Cross.

d. Furnishing emergency supplies and equipment, for example, emergency power equipement for essential facilities such as hospitals.

e. Carrying out necessary civil functions, such as public safety.

f. Elimination of hazards to health, welfare, and safety, such as debris and contaminated consumers' products.

g. Administration of Federal and State financial assistance to supplement local and State efforts.

PROTECTIVE POSSIBILITIES

139. Warning service. - The hurricane warning service of the U. S. Weather Bureau is designed to furnish advance warnings of hurricanes to the public generally. For the east coast and Gulf areas the service is centered at Miami, Florida, with four associate warning centers at San Juan, Puerto Rico, New Orleans, Louisiana, Washington, D. C. and Boston, Massachusetts. Certain geographical areas of responsibility have been established and the office responsible issues public advisories on each tropical storm (hurricane) located in its area of responsibility.

140. The Center at Miami provides liaison with other government departments, such as the Air Force and Navy. As a result there is excellent coordination in the official advisories released by government agencies. Provisions are also made at Miami for the dispatch of military aircraft for storm reconnaissance.

141. Official public advisories are issued whenever a tropical storm is detected. The advisories are issued at intervals of six hours and are numbered consecutively for each storm. Wide distribution is given to the advisories. They are distributed by the news wire services, by radio, television and newspaper, over direct radio broadcasts from Weather Bureau offices and by official distributors such as Civil Defense, Red Cross and State Police.

142. In addition to the official advisories, information on the effects expected from the tropical storm is included in public

forecasts issued for the areas likely to be affected. Weather Bureau offices issue bulletins for press and radio at other than the official advisory times in order to keep the public advised of the storm's progress.

143. Distribution from the Weather Bureau includes all news agencies in the area affected. In some cities local public weather circuits are operated which provide an excellent means for dissemination of full information on the storm's progress. Warnings such as advisories, bulletins and public forecasts, are sent on these local circuits.

144. Coastal areas are covered by forecasts of expected conditions. Warnings are issued, as required, including storm warnings and hurricane warnings. Appropriate visual flag displays are made for these warnings to obtain distribution to shipping and boating interests.

145. Provisional storm or hurricane warnings (alerts) are issued whenever necessary to advise the public in advance regarding the possibility of dangerous storm conditions developing.

146. Despite the best efforts of the Weather Bureau, the news agencies and official distributors, there is a need for wider and more expeditious distribution of hurricane warnings and advisories. Steps are being proposed to improve this by cooperating in the establishment of additional public weather circuits, creation of local warning networks in collaboration with Civil Defense organizations, and setting up additional distributors for relay of warnings to the public.

147. More extensive use of preliminary hurricane alerts is being studied. In this connection an educational program to familiarize the public with the nature and frequency of hurricanes, existing warning services and protective measures would be very helpful. Efforts should be made to enlist the aid of other groups in furthering the aims of such an educational program.

148. Modern radar equipment operating on a radio frequency of about 2800 mc., with a peak power output of about a million watts, would be of great assistance in detecting and tracking hurricanes that affect the east coast of the United States. It would contribute very importantly to the timeliness and effectiveness of the Weather Bureau's hurricane warning service. Installations at Eastport, Maine; Nantucket, Massachusetts; Atlantic City, New Jersey; Hatteras, North Carolina; Charleston, South Carolina; and Daytona Beach and Miami, Florida, would enable the precise tracking of these storms at the stage in their movement when they are most critical, with respect to great population centers of the United States, as well as to the industrial complex of northeastern United States. To illustrate the value of such installations one may consider how an installation at Hatteras, North Carolina, would be used. It has been observed that virtually all hurricanes that affect New England in any serious degree, pass within 150 miles of Hatteras. A radar site at Hatteras

could observe the minute-by-minute position of the eye of the hurricane at ranges of 150 miles or more and determine the direction and rate of motion and the changes therein, and so determine whether the hurricane would pass inland into New England or move harmlessly out to sea beyond Cape Cod. The height of the storm could also be determined as well as something of the wind velocities attending the storm.

149. Protective Measures. - The problem of providing adequate protection for both property and life against the tidal and interior flooding and the abnormal winds of hurricanes is a problem requiring considerable investigation and study. An examination of records clearly indicates that it is not uncommon for hurricane winds, often accompanied by tidal flooding, to devastate the exposed coasts of southern New England and Long Island. The potential danger to property and life resulting from such storms is directly proportional to the concentration of development in the affected area. The highly concentrated nature of modern urban industrial and commercial development in such coastal centers as Providence and New Bedford, and the similar concentration of modern coastal recreational development along much of the New England and Long Island coasts has vastly increased the potential damage to property and life resulting from such storms in the area.

150. Since the construction of effective shore protective structures is costly, such structures were not, in general, justifiable as long as relatively infrequent storms threatened only small amounts of property and small numbers of lives. In proportion, however, as population concentration and the value of affected property increases, it is clear that the ratio of benefits to costs for protective measures will increase. Damage resulting from the serious hurricanes of 1938 and 1954 make it clear that at least in some areas development may have become so concentrated as to make benefits exceed even high initial costs. The seriousness of the problem would appear

to justify the thorough investigation and study necessary to determine the most feasible means of protection, and the degree of economic justification for such protection in particular areas.

151. Hurricane damages result from abnormal tide and wave action and from floods caused by the accompanying torrential rains, as well as from abnormal winds. Damages involve economic losses to property, and loss of life. Many damages, such as those to crops and trees, and the losses resulting from the disruption of normal business activities, obviously cannot be prevented, or even relieved. Others can, in some cases, be protected against by the construction of effective barriers to water, and in other cases can be prevented by foresight in the adoption of measures which prohibit exposure to danger. Protective measures include the construction of seawalls, bulkheads, dams and dikes, groins, and breakwaters to protect established areas from the onslaught of unusual wave action and flooding; and the construction of adequate drainage systems to care for the excessive run-off created by the torrential rains accompanying hurricanes.

152. The measures which may be classified as preventive include the establishment of fully adequate warning systems, the proper education of the population in areas likely to be affected, provisions for the orderly evacuation of critical areas, the establishment of proper hurricane shelters, and the adoption of zoning restrictions preventing valuable building in areas which cannot be

adequately protected, and of building codes which will provide security to valuable property under abnormally high wind conditions. This topic has been covered in large measure in previous paragraphs. The nature and requirements of various types of protective structures are discussed in the following paragraphs. More detailed studies undoubtedly should be made to determine the economic feasibility of particular measures in critical areas.

153. Protection from abnormal tide and wave action. - In general, protection from abnormal tide and wave action can be secured by providing in greater strength and to a greater height the same measures designed to protect shorefront property, beaches, shorelines, and shipping and boating facilities against normal wave action. Such measures include the construction of seawalls, bulkheads, dams, dikes, groins, and breakwaters and the placement of beach fill. The type and extent of a structure which would be most effective or economically justifiable for a particular site depends upon the physical characteristics and economic status of the area to be protected, and upon the relationship between the cost of protective construction and the value of property to be protected. A harbor containing extensive shipping installations requires one type of structure whereas a low-lying colony of summer cottages requires another. Inasmuch as the cost of such structures is great, and their effectiveness is dependent upon adequate design, their design, development, and construction should be undertaken only by experienced technical personnel, and only after detailed studies have been made to determine the most feasible and

economically justifiable plans. Various possible types of protective works are described in the following paragraphs.

a. Seawalls. - A seawall is a structure separating land and water and designed to prevent erosion and other damage due to wave action. It is the normal means of protection against heavy seas at points where it is necessary to maintain structures near the natural shore line. A secondary function of the seawall, similar to that of a bulkhead, is to retain or prevent sliding of the land. To resist the heavy force of breaking water, it must be well designed and of heavy construction, generally of concrete, and be provided with deep, solid foundations protected by rip-rap, or stone. The height of the wall should at least be equal to that of the maximum storm wave, for full protection and generally higher to prevent overtopping by breaking waves. The ends of the wall should be tied into high ground with wingwalls to prevent flanking. The toe of the wall should be revetted with riprap to prevent undermining. The surface behind the wall should be filled to the top and paved to prevent erosion or undercutting.

(1) Seawalls are placed parallel or nearly parallel to the shoreline, and, by themselves, are most effective where there is little littoral drift along the shore, or where it is desired to maintain a depth of water along the shoreline as for a wharf or pier line. Since a wall generally produces more erosion on the water side of the beach area, where there is already a high littoral drift, further

protection by groins may be necessary to prevent undercutting of the footings of the seawall.

(2) The shape of a seawall can be a major factor in its use and effectiveness. Walls which are concave on their water side are best adapted to counteract waves breaking on them. Theconcave surface of such a wall deflects the wave seaward thereby tending to dissipate the energy of successive waves and to lessen the amount of dangerous overtopping. Such walls are particularly desirable if the beach is narrow or non-existent, and if the water level is over the base of the wall during high or storm tides. Vertical, or nearly vertical walls, although somewhat less effective against wave attack and overtopping, have the advantage of being usually easier and less expensive to construct. In addition, they are best suited for use as landing places beside navigable water, for convenience in loading and unloading vessels. Stepped-face walls provide the easiest access to beach areas, and also act to disrupt the scouring action of wave backwash. The least effective design against wave attack or overtopping is the backward sloping or convex faced wall. Although possibly more adaptable as emergency protection when the only available materials are sand bags or large stones, walls of this design should be restricted to those areas where overtopping is not a problem, or where structural, emergency, or aesthetic considerations prohibit the use of other wall designs.

(3) The costs of seawall construction are relatively high, especially if they are to be built with strength to withstand

Seawall. Winthrop, Massachusetts. New England-New York Region.

intense storm wave action and to a height adequate to prevent overtopping from maximum tides. Consequently, their construction is normally limited to those areas where the value of existing property is already so great as to demand the maintenance and protection of the shore line in its present position.

b. Dikes and dams. - Dikes and dams are sturdy barriers designed to prevent or control the passage of water by closing off a particular area. They may, like seawalls, be built parallel to the area to be protected, or they may be constructed across a waterway. They are variously constructed of earth, concrete, or steel. Earth is gaining in popularity because of its abundance and relatively low cost. Where dikes or dams block a waterway, gates must be provided to control the flow of water. Where waterways are navigable, facilities, usually in the form of locks, must be provided for the passage of ships.

(1) Dikes and dams have been proposed for protecting several localities in New England from the damaging effects of tidal flooding. Generally, these proposals require the provision of pumping stations to accomplish interior drainage during the period when gates may be closed. At some localities, however, where interior drainage is small compared to the size of impoundment, it would be possible to omit pumps and to install weirs with gates, or drainage gates with flap valves.

(2) Dikes and dams are usually substantial structures built to withstand severe stresses. Consequently their construction is costly and can be economically justified only when substantial

damages can be prevented.

c. Bulkheads. - A bulkhead is similar to a seawall except that its function is primarily to resist earth pressure and only secondarily to withstand wave action. Actually a given protective structure may be called a seawall at one location and a bulkhead at another, depending on its purpose. In general, however, bulkheads are less stable and are best to afford protection to bluffs from erosion or to maintain deep water along a wharf or a pier.

(1) Bulkheads, which are protected by a permanent beach berm from the direct impact of the waves, may be built to a height of approximately two feet above the height of the maximum wave uprush, or to a height equal to that of the fill which they are designed to retain. They are most commonly constructed of sheet steel piling, although many are built of concrete or timber. The major factor determining the choice of building material is the susceptibility of the structure to direct wave attack and salt water erosion. The greater the exposure to such attack, the greater the necessary strength. Whatever material is used, however, care must be taken to adequately protect the foundations of bulkheads from scour or settlement by protecting the base of the structure with riprap or large stones.

(2) Bulkheads have the advantage of low initial cost compared to the generally more elaborately constructed seawall. Maintenance costs however, are relatively high. Consequently, the selection of this type of protective structure must be predicated on

Bulkhead. Scarborough Beach, Rhode Island. New England-New York Region.

an annual benefit-cost ratio. Studies of the economic justification of bulkhead construction must consider the extent of continued use and the possible future development of the area to be protected.

d. Groins. - A groin is a shore protection structure, usually built perpendicular to the shoreline, which functions to trap the littoral drift or to retard erosion of the shore. It is narrow but long enough to extend from a point landward of the shoreline out into the water a sufficient distance to provide stabilization of the shoreline.

(1) There are several types of groins: permeable or impermeable, high or low, and fixed or adjustable. Permeable groins contain openings of sufficient size to permit the passage of appreciable quantities of littoral drift. Impermeable groins are generally solid structures which prevent any littoral drift. Some permeable stone groins may, however, become impermeable from heavy marine growth. A permeable groin appears in many cases to be preferable since an impermeable structure, in building up an accretion of sand on the up-drift side, prevents the necessary replenishment of sand on the down-drift side. Many factors must be considered in selecting the number and size of the openings in a permeable groin: the slope of the beach; the height, length and angle of approach of the waves; the magnitude of the littoral drift, and the size of the beach material. The choice between permeable and impermeable groins must be based upon a careful study of all factors in the area concerned.

(2) The height of a groin depends on the volume of sand movement at the location where protection is desired. At the base of a headland or reef, or at the entrance to a bay or inlet where it is not necessary to maintain a sand supply downdrift of a groin, it may be built to a height that would completely block the passage of all material moving in that area. However, where it is desirable or necessary to maintain a sand supply downdrift of the groin, it may be built to such a height as to allow overtopping by storm waves or by waves at high tide. Such low impermeable groins serve the same function as a permeable groin, and are more stable and positive in their action.

(3) The majority of groins are constructed as permanent structures, but the adjustable type is sometimes used where it is desirable to maintain the downdrift beach while inducing beach building updrift of the groin. These groins consist of adjustable batter boards between piles. The batter boards are positioned to permit the accumulation of a desired amount of sand in stages. At the end of each state, sand is allowed to pass over the groin and thereby replenish the downdrift beach.

(4) The shape and dimensions of a groin depend on the wave forces to be withstood, the type, the material with which it is to be built, and the construction methods used. The length is determined by the depths in the offshore area and the extent of the littoral drift it is desired to intercept. The most desirable shape of groin is one of trapezoidal cross-section.

Groins. Winthrop, Massachusetts. New England-New York Region.

(5) Groins may be constructed of concrete, steel, stone, timber, or combinations thereof. Most concrete groins are made up of precast blocks with flexible joints laid in place on the sand, gravel, or a mat of crushed stone, then connected with a poured concrete blanket or cap after they have settled. Although susceptible to corrosion, steel sheet pile groins with interlocking joints have proven satisfactory against wave attack, and provide positive sand-tight connections between adjacent piles. The steel piling is normally used in conjunction with timber members and bracing, all creosoted for maximum protection against marine borers. Stone groins are usually constructed of either rubble or of cut stone blocks.

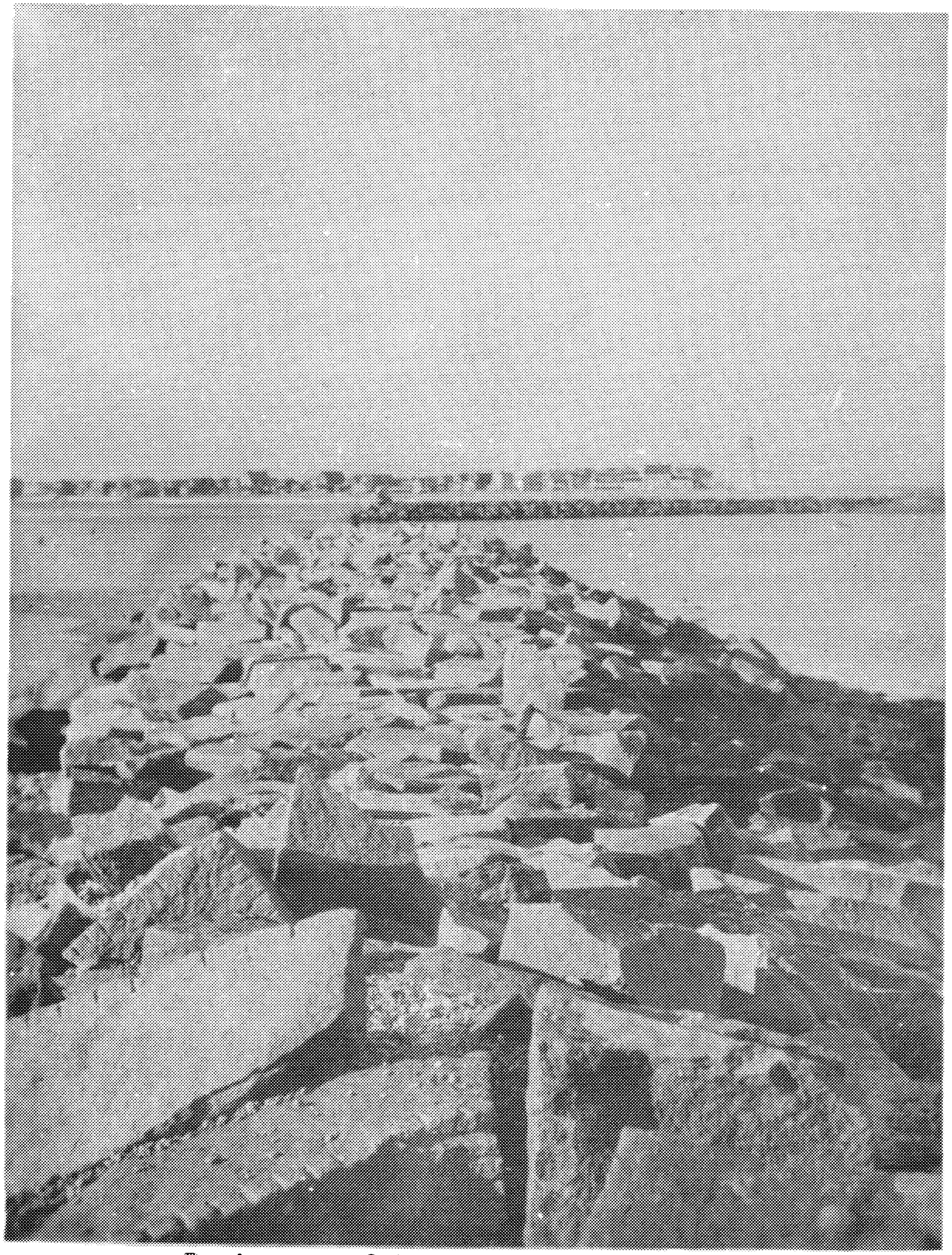
(6) For an impermeable stone groin, the voids between the rubble-stones used in the core of the structure are filled with fine material or cement grout. This core is then capped with stones of sufficient weight to protect the structure from anticipated wave damage. Stone block groins, comprised of blocks ranging in weight from two to six tons apiece, are generally permeable in nature, but may be made impermeable by placing a steel sheet pile diaphragm down the center of the stone blocks. The most common type of timber groin is an impermeable structure composed of sheet piling supported by wooden timber and piles. The wooden members must be given the maximum treatment of creosote.

(7) In selecting the type of groin needed at a particular location, many factors must be considered. These include the topography of the area, the soil composition, the character of the foundation,

the range of tide, littoral drift, wave characteristics, tidal currents, and the economics of the individual project. Where an extensive beach area is to be protected, a group of groins is usually necessary and the cost thereof may be excessive.

(e) Breakwaters. - A breakwater is a barrier of solid construction built out into the open sea to break the force of the waves and to provide comparatively smooth water inside for the anchorage of vessels or their landings at wharves or piers. The breakwater differs from the jetty in that the jetty is a barrier (generally one of two parallel barriers) usually built at the mouth of a river in such a form as to induce the river currents to scour the bottom of the harbor entrance and remove from the channel, sand, silt, and earth, or to prevent the shoaling of the protected channel by littoral drift from beaches adjacent to the river mouth. Properly constructed, breakwaters are a highly efficient means of protecting against the destructive force of wave action. The characteristics and uses of breakwaters are described in the following paragraphs:

(1) Breakwaters may be classified as connected or detached, as exposed or submerged. A connected breakwater is one which is built out into the sea from an attached point on land; a detached breakwater is one which is built entirely within the water. Exposed breakwaters are those that are uncovered only at low stages of tide as well as those never completely submerged. Submerged breakwaters are those which have their tops below low water level, their function being to retain beach fill or to reduce the force of waves by causing them to



Breakwaters. Scituate, Massachusetts.
New England-New York Region.

break before reaching the shore. The general dimensions of the breakwater are governed by the prevailing height, length, and force of the waves which it is designed to provide protection against. The extent to which the submerged breakwater will reduce wave action is dependent upon the ratio of the depth of water over the breakwater to the depth of water at the site.

(2) The height of the exposed breakwater necessary to prevent significant overtopping should be $1\frac{1}{3}$ times the height of the design wave over the design water level. In most cases the slope of the seaward side should be flatter than that of the landward side, the slope being dependent on the size of the design wave and the weight of the stones or blocks of which the breakwater is built. Needless to say, the superstructure of the exposed breakwater must be designed to withstand the tremendous direct force of wave attack on the seaward side and the force of the receding wave action on the landward side.

(3) Since a breakwater is usually an expensive structure, the type to be used at a particular site is largely dependent upon the amount of protection which is economically justifiable at that site. Important factors to be considered in determining design are the magnitude of wave action, the height and length of waves, the tidal range, the depth of water at the proposed site, the topography of the bottom, and foundation conditions. Of the submerged and exposed types, the latter is of course by far the more susceptible to damage from wave attack, although the destructive forces of the sea extend to sufficient depths to damage submerged ones.

In all cases the core material must be protected by heavy blocks or rubble.

(4) Breakwaters may be constructed of stone, concrete, steel, timber, or various combinations of these, and designs vary widely according to a variety of factors at the particular site to be protected. The selection of material depends upon cost, adaptability, and availability at the proposed site. The most common general designs are described below:

(a) A rubble-stone mound structure may be used in any depth of water on any kind of foundation. This type has generally been used in New England. Such structures are easily repaired if damaged, or if settlement occurs, and the reflected wave action is less severe than that from a solid wall. The advantages of economical maintenance are partially offset, however, by the high initial cost of this type of structure. This high cost is largely attributable to the large quantity of material needed, and is proportionately increased if necessary material is not readily available.

(b) A stone-and-concrete breakwater may be either a rubble mound in which the voids are grouted with concrete, or a massive concrete superstructure on a rubble mound substructure. Both types tend to be relatively economical, especially in deep water, since relatively small quantities of material are needed. The rubble mound foundations must be protected from scour, and given time to settle before the concrete superstructure is added.

Offshore breakwater. Winthrop, Massachusetts. New England-New York Region.

(c) A concrete caisson breakwater is suitable for depths from 10 to 35 feet. The caissons, precast as hollow, re-inforced concrete shells, are floated into position, settled on a prepared foundation, filled with stone or sand, then capped with concrete slabs or cap stones. Heavy riprap is usually placed along the caissons to protect against scour or horizontal displacement.

(d) Steel sheet piling breakwaters may be used where storm waves are not severe. The sheet piling may be in the form of a wall, or as a double wall with the space filled with stone or sand. This type of structure is generally economical and easy to build, but it is susceptible to the corrosive action of the salt water and the abrasive action of the sand. Constant maintenance is necessary. Another variation of sheet-piling breakwaters is the cellular steel type, which requires little maintenance and is suitable in depths up to 40 feet and on all kinds of foundations.

(e) Timber crib structures, used in the construction of breakwaters, are similar to the caisson type in that they are floated into place in sections, settled into position on a prepared foundation by filling them with stone. They are then capped with timber, concrete, or cap stones. The superstructure and decking of cribs set on a rubble-mound foundation are often of timber to allow for settlement of the crib. This type of structure is suitable for depths up to 50 feet or more, except where marine borers are present. Foundation stabilization is similar to that for the caisson type.

154. Zoning. - The recurrence of hurricanes has suggested the desirability of zoning in coastal areas susceptible to tidal flooding. Portions of large cities as well as residential areas in southern New England and Long Island suffered heavily from tidal flooding accompanying the hurricane of 1938 and again in 1954. Whole summer colonies were wiped out in 1938 and again in 1954. The recurrence of the devastation at an interval of only 16 years has convinced many State, City and Town officials of the desirability of revised zoning. Some towns have discovered that the tax income from summer cottages situated along the ocean front is insufficient to pay for necessary services, particulary when roads, and water lines may be periodically destroyed. A possible solution of the problem may be found in the purchase of coastal beaches by towns or states. These areas could be reserved in an unoccupied state for public enjoyment. Adequate access roads would be required to enable orderly evacuation of the beaches at the approach of a hurricane. Proper restriction measures along the exposed, low lying coastal areas appear to offer a feasible method of preventing considerable damage and suffering from tidal flooding. Zoning measures which might be adopted would have to be designed for the particular area to be protected.

155. Protection from floods caused by hurricane rains. - The copious rainfall associated with cyclonic storms presents no new problems in protecting interior areas from floods. The flood

control structures in the flood control plans for the major river basins would provide a high degree of protection from floods resulting from hurricane rains.

156. Drainage improvements. - Drainage improvements consist of modernizing and increasing the capacity of storm drainage systems in built-up areas and increasing channel and culvert capacity on interior drainage areas to permit more rapid dissipation of excessive runoff. The need for providing additional facilities in built-up areas was not forcibly illustrated during the 1954 hurricanes except at certain localities such as New London, Connecticut, where the storm drainage system was previously known to be inadequate. The following subparagraphs discuss drainage problem areas and methods of dissipating excessive runoff.

a. Storm sewers. - In general, the design of storm sewers depends upon the degree of economically justifiable protection required to provide against the damage and inconvenience resulting from over-charged sewers. It is not always economical to construct storm sewers sufficiently large to discharge the runoff from extreme storms that are likely to occur at infrequent intervals. Therefore, it appears that storm sewer capacity in New England communities may not be expected to be sufficient to care for high runoff such as occurred in some localities during Hurricane Edna. However, where unusual problems exist, as at New London, sufficient study should be undertaken to determine what measures will be economically feasible.

b. Interior areas. - Drainage problem areas along interior streams have existed for many years. Consequently, many of these areas have not been developed for residential, commercial, and industrial use. These areas invariably suffer during periods of heavy precipitation, because downstream channel capacities are insufficient to discharge the heavy runoff from the flat terrain of low elevation. In addition, due to a flat slope in the drainage rivers, the channels are often restricted by sand bars. Following flood periods, the water level of such rivers recedes to normal very slowly causing serious inconvenience to all the owners along the particular river.

(1) The Concord River Basin provides an example of poor interior drainage. Flooding in this area following Hurricane Edna caused considerable damage by flooding the cellars of commercial establishments and residences. Remedial measures for this and

other areas which are subject to similar flooding during periods of heavy localized precipitation can be formulated only through detailed engineering investigations.

157. Protection from abnormal winds. - In general, there is no complete protection or relief from damages caused by abnormally high winds. In addition, certain measures which might be taken to minimize the possibility to some kinds of damage are of a nature likely to be unpopular. The recent hurricanes experienced in the New England-New York Region have, in each case, uprooted and broken many trees, seriously damaged vegetable and flower gardens, stripped fruit from trees and frequently destroyed the trees themselves, and flattened fields of corn, rendering them worthless except for silage. In addition, hurricane winds have done large amounts of minor structural damage to homes and other buildings, stripping roofs, doors, porches, shutters, television antennas, chimneys, and other exposed building fixtures. In commercial establishments, many plate glass windows and advertising signs have been destroyed. For the most part, prevention of such wind damages as these is entirely impractical. Heavy damages to power lines, houses, and automobiles, as well as the danger to human lives resulting from falling trees are probably equally impracticable to prevent. Although much of this type of damage, particularly that occurring to power lines, could be prevented by the removal of shade trees, public sentiment would

probably resist such removal on aesthetic grounds. Some protection might be obtained by careful selection of shade tree species. Cases of major structural damage due to wind were uncommon in the 1954 hurricanes, although one large television transmission tower was blown over and several church steeples demolished. Such damages as these undoubtedly could have been prevented by more adequate building codes and suitable maintenance practices. The two measures most often considered for the reduction or prevention of hurricane wind damages are the revision of building codes and the use of underground utility lines. These are discussed briefly in the following paragraphs.

a. Revision of building codes. - The extent of structural damage caused by wind alone in the recent hurricanes appears to indicate the desirability of more stringent building regulations for major installations. Major structural damage could be eliminated or minimized if all industrial and commercial installations were designed to withstand winds exceeding those already experienced in the area. Towers, signs, and other similar structures should be covered in appropriate revisions of the building code. Such provisions would not substantially increase the cost of the affected structures.

(1) The adoption of revised building codes for residential structures of seasonal nature, such as summer cottages, presents economic problems. Major wind damage to these structures was not generally extensive, although in some localities exposed buildings were apparently demolished by the force of the wind.

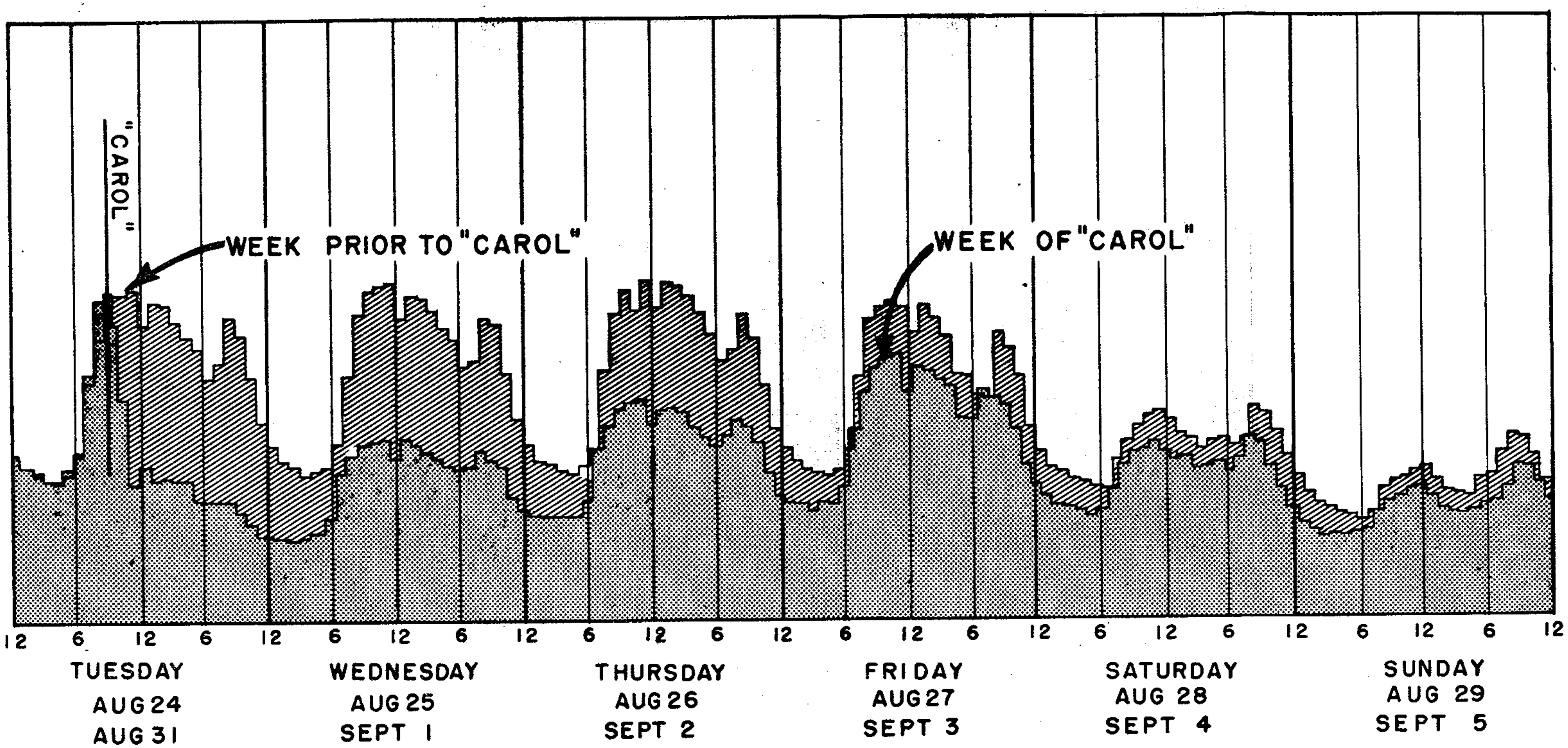
Evidence indicates that in certain areas wind alone was sufficient to destroy cottages before tidal flooding occurred, which, in any event, would have destroyed them. There is insufficient evidence, however, to indicate that major revisions in building codes are necessary for summer residences situated above the reach of expected tidal flooding. Since individual wind damage was relatively minor and only minor human suffering can be attributed to wind alone, there appear to be serious objections to the establishment of stringent building codes for this type of structure. This is particularly true since any major structural changes would require costly provisions in these buildings which might prohibit the enjoyment of ownership by a large segment of the population.

b. Underground utilities. - The 1954 hurricanes caused severe interruptions of electric and telephone service. As a result, there has been popular agitation for placing all utilities underground as a means of preventing future periods of interrupted service. The following paragraphs discuss the effects of hurricanes on electrical and communications lines, and the problems incident to underground placement of wires.

(1) Effects of hurricanes on utilities. - The electrical utility companies and the communications companies suffered severe losses during the 1954 storms. Service throughout the

region was curtailed for varying periods. Major damage was caused to electrical distribution lines and telephone lines. Major transmission lines along cleared right-of-way were relatively unscathed. Distribution and telephone lines usually are placed adjacent to the public highways and streets, where they compete for space with shade trees. During the 1954 hurricanes, entire trees or limbs were blown across the telephone and power lines. Over 861,000 of 1,500,000 customers in New England served by four utilities were reported to be without power for periods up to one week following Hurricane Carol and for a shorter period following Edna. Many of the residential customers depended on electricity for refrigeration, cooking and water supply in addition to lighting. About 250,000 telephones were reported to be out of service in Massachusetts, Rhode Island, New Hampshire and Maine and a large number in Connecticut. Along the coast, tidal flooding of giant thermal electric plants rendered the stations inoperable.

(2) The effect of the storm on utility generation of the New England Electric System is graphically illustrated on the load chart shown on Plate 81. The New England Electric System publication "Contact" reported as follows: "High water and wind-blown material hit the steam stations knocking out 275,000 kw. Then another 100,000 kw followed by 160,000 more. ....



NOTE:
Reprinted from "contact" Oct. 1954
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SPECIAL SUBJECTS-REGIONAL

COMPARISON OF LOAD
WEEK OF HURRICANE "CAROL"
AND PRECEDING WEEK
NEW ENGLAND-ELECTRIC SYSTEM
NEW ENGLAND NEW YORK INTER AGENCY COMMITTEE
NOVEMBER 1954

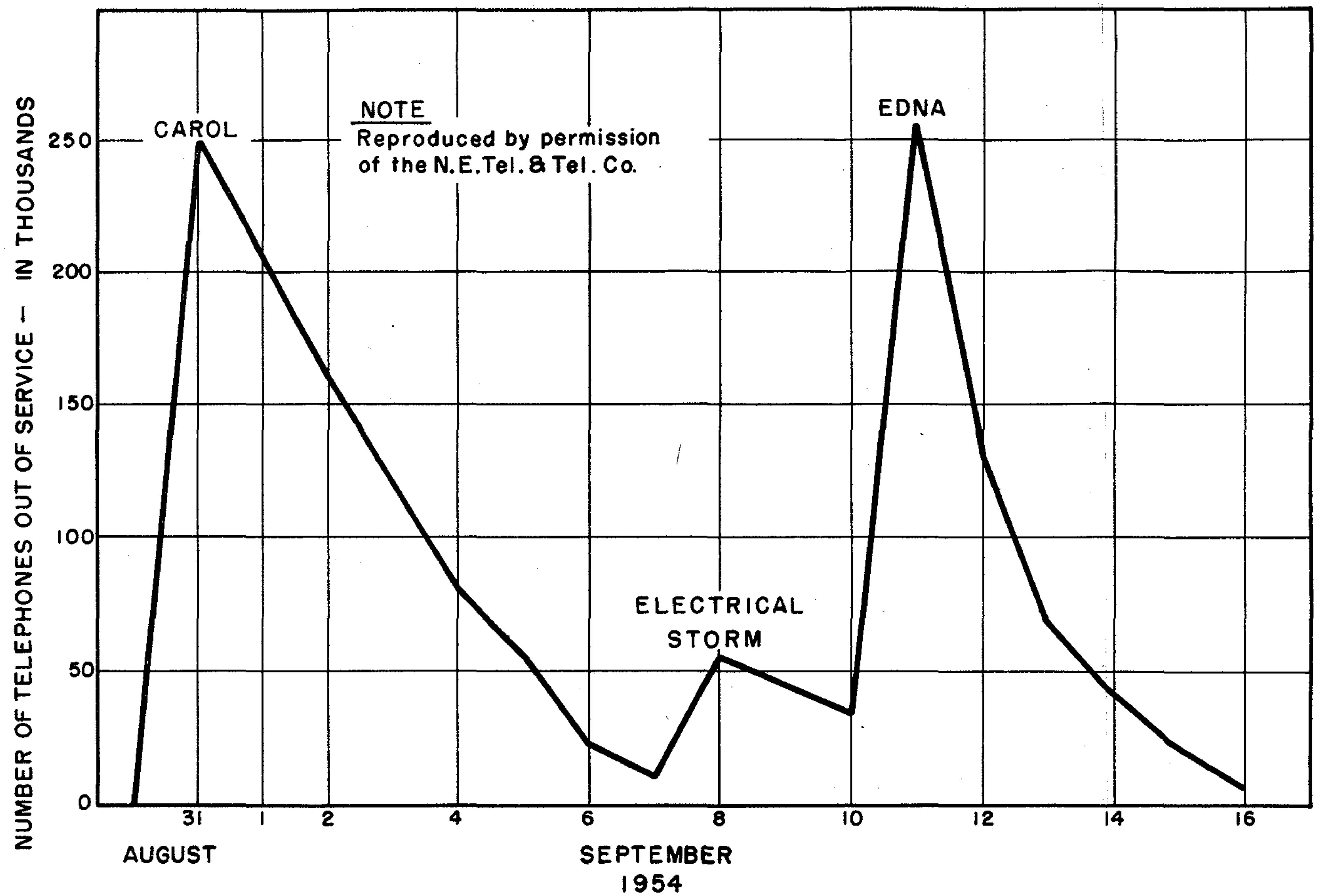
.... The resources of the hydro plants were put to maximum use." Plate 81 illustrates this drop in load and also shows the rapidity with which this utility mobilized its forces, with outside help, repaired lines and equipment, and restored normal operation. Plate 82 shows the effect of the hurricanes on the communications system of the New England Telephone and Telegraph Company and indicates the outstanding work accomplished in restoring telephone service, with the help of crews from other areas.

(3) Benefits from underground placement of utility lines. - The utilities and the communication companies have accomplished some underground placement of lines, principally in the metropolitan areas. The business section of Providence, and several small communities are served by underground lines. In Boston, the Boston Edison Company in recent years has had a program for placing four miles of wire underground annually. The major benefit of underground utilities, aside from aesthetic benefits, would include more dependable service with fewer and shorter interruptions than occur with above ground lines. However, when underground lines have been inundated, there is a considerable delay in drying them out before service can be restored.

(4) Cost of underground placement. - A major deterrent to underground placement of utility lines appears to be the installation and maintenance costs not only to utility companies, but in

many cases to householders and business customers. A study made recently in Connecticut indicated that it might cost 25 times as much for underground placement of electrical distribution lines as for conventional above ground construction. Poles required for street lighting purposes would add to this cost. Inasmuch as the greatest damage to utility lines resulted from blowdown of trees, service conditions could be improved by providing unimpeded rights-of-way for these services. This might be publicly unacceptable as it would entail the removal of many fine trees. Additional study of the matter of underground placement of utilities is desirable. In this connection, the Massachusetts Department of Public Utilities has announced that it is making a study of the cost of placing power and telephone lines underground. The 1955 session of the Massachusetts Legislature will consider bills which would require utilities to place overhead lines underground.

(5) Conclusion. - Underground placement of power and telephone lines is feasible in populated areas as indicated by existing installations. Extension of these lines might prevent some of the major service interruptions which occur during storms of great intensity. Other factors, such as protection of the coastal thermal generating plants should be considered. Considerable study is required to determine the economic feasibility and desirability of underground lines. Such a study should be made and the results publicized.



SPECIAL SUBJECTS–REGIONAL

PROGRESS OF RESTORATION

NEW ENGLAND TEL. & TEL. CO.

NEW ENGLAND-NEW YORK INTER-AGENCY COMMITTEE

NOVEMBER 1954

158. <u>Hurricane shelters.</u> - It has been noted herein that tidal flooding caused the greatest damage to life and property. Wind alone, although destructive, did not generally endanger well-constructed buildings. Consequently, the matter of providing shelter for evacuees from the threatened area is primarily important in the coastal areas. Public shelters are not needed at inland points except where interior river flood victims require assistance. During Hurricane Carol, and preceding Hurricane Edna, hundreds of people were evacuated from the coastal areas of Connecticut, Rhode Island and Massachusetts and found shelter with friends, in hotels, or in public buildings. Emergency relief agencies provided food and beds for many people. Existing disaster and relief agencies were, in most cases, able to provide for the needs of the hurricane victims. Public buildings were generally adequate to give the short-term quarters required.

159. Experience gained during Carol indicated that permanent planning was needed to prevent confusion. People living in areas subject to tidal flooding should have advance knowledge of the location of facilities available to them in periods of danger. Beds, bedding, food, non-electric cooking facilities, sanitary provisions, and medical attention should be readily available on short notice. It is possible that in the future the coastal areas should be evacuated promptly upon official warning of the approach of a storm.

255

Some means should be available for the temporary shelter of an increasing number of people. No special structures are required. Emergency shelters, such as are common in the West Indies, are not needed in New England, as public and private permanent type structures are generally sufficiently strong to withstand the force of the winds.

160. Protective measures for specific localities. - Various methods which might be employed for protection against tidal flooding have been described in the preceding paragraphs. The application of some of these measures is discussed in the following paragraphs for certain localities which received substantial damage during Hurricane Carol. Many other localities also received damage and might well warrant protection. Studies of these localities as well as detailed consideration of the areas included in the discussion below might form the subject of special studies of greater scope than the present report.

a. Fairfield, Connecticut, area flooded. - The town of Fairfield (population 30,489 in 1950) is located on the north shore of Long Island Sound, immediately west of and adjacent to the city of Bridgeport, Fairfield County, Connecticut. The area subject to tidal flooding covers about 1-1/2 square miles, extending laterally about 2-1/2 miles from South Pine Creek Road on the west to Ash Creek, the Bridgeport-Fairfield town line on the east, and extending inland from the shore a maximum distance of 1.3 miles and an average distance of 0.6 mile. A barrier beach, 7 to 10 feet above mean high tide, extends along the shore from the mouth of Pine Creek to the mouth of Ash Creek. Over 250 summer and year-round homes have been constructed along Fairfield Beach Road on top of this barrier beach. Behind the beach, on land only slightly higher than spring tides, are over 500 permanent homes, a veterans' housing development, an elementary school, valued at $750,000, the town sewage treatment plant and the town garage. The assessed valuation of homes in the flooded area is reported to be nearly $10,000,000. The extent of tidal flooding is shown on Plate 83.

(1) Cause of flooding. - Tidal flooding has occurred in two ways. At the time of extreme high tides and a southeasterly wind, the low lands behind Fairfield Beach Road are inundated by tide waters backing up Pine and Ash Creeks at either end. Such flooding has occurred three times in the past four years - on 25 November 1950, 7 November 1953, and 31 August 1954.

(2) Extent of damage. - Hurricane Carol, on 31 August 1954, not only caused tidal flooding through Pine and Ash Creek but in addition breached two places in the barrier beach and overtopped the beach at the end of Beach Road, flooding the built-up area to a maximum depth of five feet. Many of the summer cottages and homes along Fairfield Beach Road are protected by seawalls which average about six feet in height above mean high tide. According to residents of the area, the waves during Hurricane Carol splashed over these walls in places but no substantial damage resulted from this cause. About 2,000 feet southwest of the junction of Reed Road and Fairfield Beach Road, there are four cottages in front of which there is no seawall. Waves scoured beneath these cottages, washing substantial amounts of sand onto Fairfield Beach Road but causing only minor structural damage. Wave action also scoured a hole under the Penfield Bathing Pavilion, depositing a heavy layer of

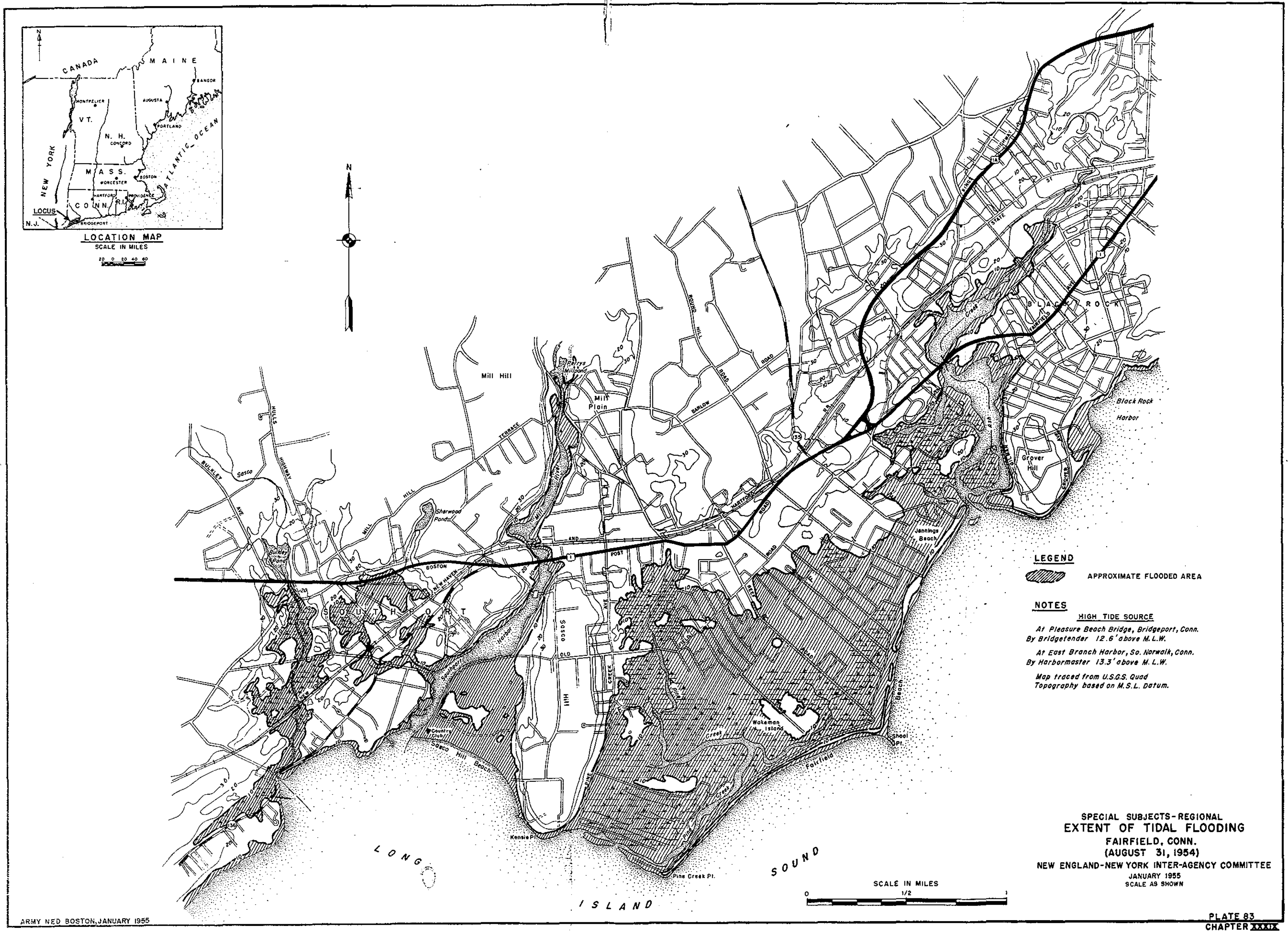


PLATE 83
CHAPTER XXXIX

sand near Penfield Road. At the end of Beach Road, the waves overtopped the barrier beach, depositing sand on Beach Road to beyond Fairfield Beach Road.

(3) Possible remedial measures. - Protection to the area from flooding through the Pine and Ash Creek ends can be quite readily accomplished by means of low dikes not exceeding 10 feet in height, extending from high ground at either end and tying into the barrier beach at suitable locations. Pipes with tide gates would be necessary to provide drainage from interior runoff and the two creeks.

(4) There are three possible methods of preventing damage from frontal tidal action: (a) construction of a concrete or masonry seawall for the entire length of the barrier beach tying into the two dikes previously described; (b) the artificial placement of sand to increase the barrier beach to such height that it would not be overtopped; and (c) the raising of Fairfield Beach Road to an elevation above any anticipated tidal heights, extending it as necessary to tie into the above-described dikes. The first method would be extremely costly and might meet with considerable opposition by owners of the summer cottages along Fairfield Beach Road since it would interfere with their view of and access to the beach. The second method might well be ineffective due to subsequent erosion of the beach and ultimate breaching under tidal action unless the fill were heavily riprapped, a procedure which would destroy its

use as a beach. Raising Fairfield Beach Road would appear to be a reasonable solution to the problem. While this method would not afford protection to the cottages along the beach, it would provide protection to the permanent homes and public buildings in the low area behind the barrier beach.

(5) Costs and benefits. - No estimate of the cost for protection of the area has been made. It is estimated that damages due to tidal flooding at the time of Hurricane Carol amounted to $489,000. The tidal flooding in November 1953 covered approximately the same area as that of Hurricane Carol and damages were of comparable magnitude.

b. New London, Connecticut, area flooded. - New London is located on the west bank of the Thames River, tidal estuary, approximately 2.5 miles above the point where the river flows into Long Island Sound. The city had a population of 30,551 in 1950, and is commercialized along the entire length of New London Harbor, which extends three miles above the mouth of the river. Several military installations and the Coast Guard Academy are also located in the area. The area flooded consisted of all the shorefront land and property adjacent to the river within the limits of the township of New London. The extent of tidal flooding is shown on Plate 84.

(1) Cause of flooding. - Tidal flooding is caused principally by a combination of hurricane winds occurring at the same time as the normal high tide. The mean range of tide is 2.6

feet, but during Hurricane Carol the tide reached an elevation of 10.5 feet above mean low water. The city of New London, lying along the west side of the open harbor, is particularly susceptible to damage from storm winds approaching from the south and southeast. Shore protective works are not extensive, consisting principally of low walls and revetments to protect private property along the southern beach and residential area, and a few bulkheads and walls in the upper commercial section of the harbor.

(2) Extent of damage. - It is estimated that the damages incurred by Hurricane Carol, which arrived at the time of flood tide, were 70 percent due to flooding, and 30 percent due to wind. Damages incurred by Hurricane Edna which passed more to the east of New London and occurred during ebb tide, but brought considerable precipitation with it, were due 60 percent to rain and 40 percent to wind.

(3) There was no loss of life from either storm, and although some injuries were sustained, none were serious. One thousand persons were evacuated during the first hurricane. As a result of earlier warning about 1500 persons were evacuated before the arrival of Hurricane Edna.

(4) Along the coast, south of the city, the major damage from Hurricane Carol was to beaches and private property. The New London Lighthouse was not affected although the tide rose as far as its base. Many sections of Pequot Avenue, which closely follows

the shoreline, as well as the docks and warehouses below Greens Harbor, were under water. Numerous houses in this area received some water damage, but the majority of them were sufficiently well constructed to sustain only slight damage.

(5) The heaviest loss occurred in the center of the city where about 450 automobiles, numerous stores, between 300 and 400 homes, scores of buildings, and the majority of the wharves and warehouses were inundated. A long stretch of the Central Vermont Railroad, and several sections of the New York, New Haven and Hartford Railroad's shoreline track were under water during the hurricane. At one point on the shoreline, 15 Coast Guard buoys were on the track. The loss of boats, both commercial and private, was high, and the damage to wharves and docking facilities very heavy. At one dock alone the estimated loss to boats and docks was nearly $70,000.

(6) The damage incurred in Hurricane Edna was considerably less than in Carol principally because the center of the storm passed some distance from the city when the tide was near its ebb. In addition, the city was more adequately advised of the approach of the storm so that precautionary measures were taken to safeguard property, food-stuffs, and merchandise. Considerable damage was caused, however, by heavy precipitation over a short period which far exceeded that during Hurricane Carol. Approximately 50 percent of the houses had water in their cellars. Nearly one-half

of the total damage was from food spoilage. Flooding of numerous streets resulted in many cases from overflowing storm sewers. Similar overflowing during Hurricane Carol resulted when the high tide forced water to back up in the drains.

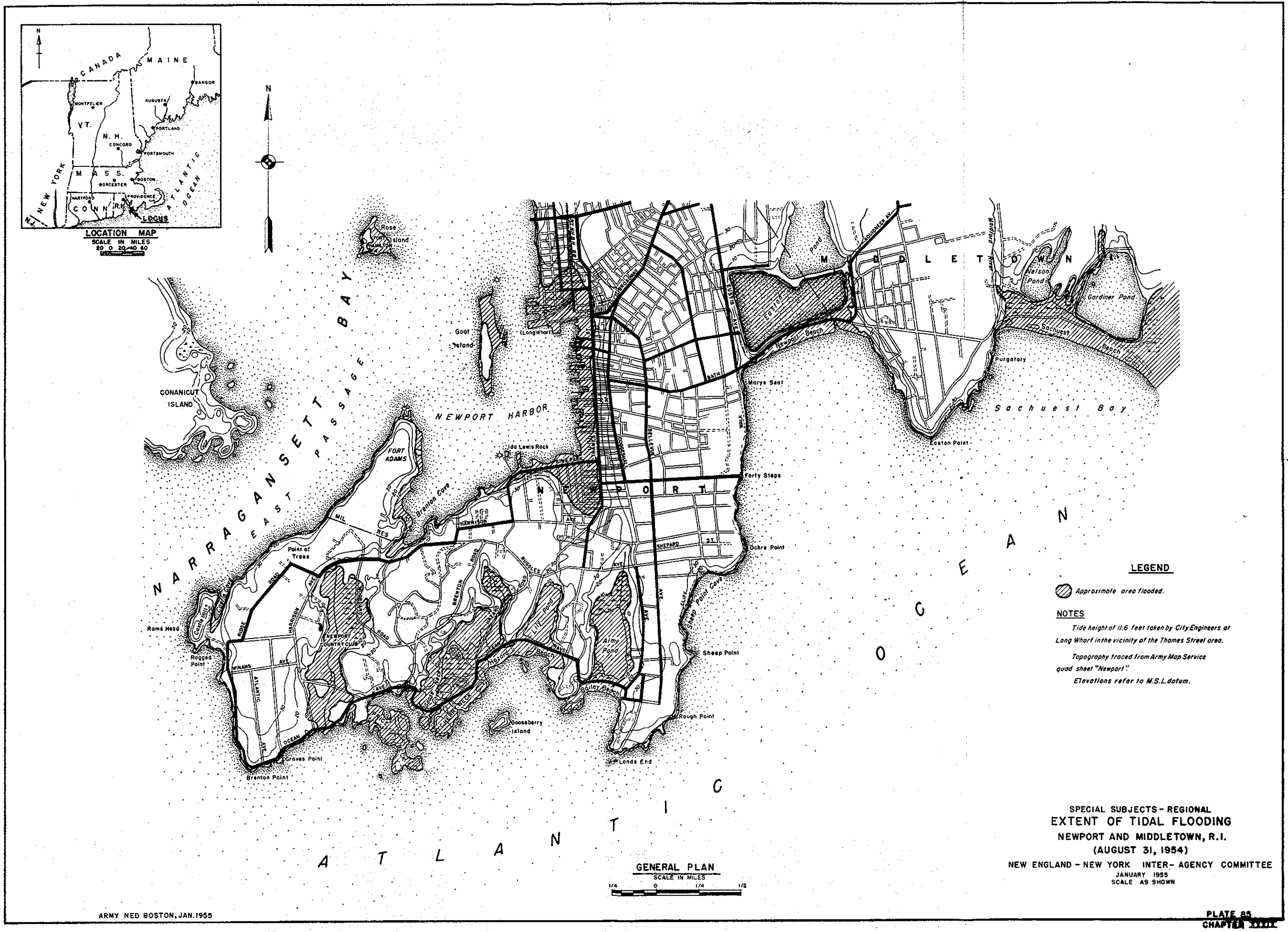
(7) The total estimated damage caused by both hurricanes at New London was $2,908,000, 70 percent of which ($2,066,000) was inflicted by Hurricane Carol and 30 percent by Edna. Tidal flooding alone caused damage estimated to total $1,383,000. These figures are exclusive of damage to State facilities, railroads, communications and power. Damage estimates for these items afforded no locality breakdown.

(8) <u>Possible remedial measures.</u> - New London officials and residents greatly desire protection from tidal flooding. The community, comprising an area six miles long and one mile wide, is topographically restricted from further growth. As a center for a resort area, with no large industries, it depends to a considerable extent on the tourist and vacation trade for its income. It is felt that a frequent recurrence of tidal flooding and damage will discourage the tourist trade, thereby directly and indirectly harming the small businesses. At the present time, it appears that seawalls would be the only measures which would offer protection against extreme tides. Seawalls would have to be built to such height that in many cases construction costs might exceed the value of the protected property. A more extensive study of the area is necessary to determine the economic feasibility of a

protective program. The principal cause of flooding from excessive surface run-off is the inadequacy of the city storm sewer system, which often overflows with rainfalls of only moderate intensity. City officials are aware of the situation and are working on plans to redesign the system.

c. Newport, Rhode Island, area flooded. - The city of Newport, with a population of 37,564 in 1950, is situated at the southern end of Aquidneck Island, with the principal industrial and commercial activity being located on Newport Harbor, 2.5 miles above the mouth of Narragansett Bay (East Passage). The city is thickly settled and contains many commercial establishments. A Naval Training Station, located north of the city, is one of many military installations in this area. The southern part of the island is the location of numerous spacious residences and summer homes. Two public beaches on the south shore, and one below Easton Pond south of the road between Newport and Middletown, are extensively developed bathing areas. The area subjected to flooding includes the beaches and shoreline around the "boot" of Aquidneck Island; the wharves, warehouses, and waterfront property in Newport Harbor, and military reservations and installations at various locations in this lower section of Narragansett Bay. The extent of tidal flooding is shown on Plate 85.

(1) Cause of flooding. - Tidal flooding at Newport is caused by a combination of hurricane winds occurring at the same time as the normal high tide. The mean range of tide at


LOCATION MAP
SCALE IN MILES
20 0 20 40 60
CANADA
MAINE
VT.
N.H.
MASS.
CONN.
R.I.
NEW YORK
ATLANTIC OCEAN
LOCUS
BANGOR
AUGUSTA
MONTPELIER
PORTLAND
CONCORD
PORTSMOUTH
BOSTON
WORCESTER
HARTFORD
PROVIDENCE
N
NARRAGANSETT BAY
EAST PASSAGE
NEWPORT HARBOR
CONANICUT ISLAND
Rose Island
Goat Island
Long Wharf
Ida Lewis Rock
FORT ADAMS
Brenton Cove
Point of Trees
Rams Head
Ragged Point
Brenton Point
Graves Point
Gooseberry Island
Bailey Beach
Almy Pond
Lily Pond
NEWPORT COUNTRY CLUB
NEWPORT
MIDDLETOWN
Easton Pond
Newport Beach
Nelson Pond
Gardiner Pond
Sachuest Beach
Sachuest Bay
Purgatory
Easton Point
Marys Seat
Forty Steps
Ochre Point
Sheep Point Cove
Sheep Point
Rough Point
Lands End
ATLANTIC OCEAN
LEGEND
Approximate area flooded.
NOTES
Tide height of 11.6 feet taken by City Engineers at Long Wharf in the vicinity of the Thames Street area.
Topography traced from Army Map Service quad sheet "Newport".
Elevations refer to M.S.L. datum.
GENERAL PLAN
SCALE IN MILES
1/4 0 1/4 1/2
SPECIAL SUBJECTS - REGIONAL
EXTENT OF TIDAL FLOODING
NEWPORT AND MIDDLETOWN, R.I.
(AUGUST 31, 1954)
NEW ENGLAND - NEW YORK INTER - AGENCY COMMITTEE
JANUARY 1955
SCALE AS SHOWN
ARMY NED BOSTON, JAN. 1955
PLATE 85
CHAPTER XXIV

this locality is about 3.5 feet. During Hurricane Carol the tide reached a peak elevation of about 12.5 feet above mean low water. There are numerous shore protection works, consisting principally of sea walls and bulkheads.

(2) <u>Extent of damage.</u> - Tidal flooding was extensive, and the losses extremely heavy in Hurricane Carol. In the vicinity of Long Wharf, the water rolled in as much as 2,000 feet beyond the face of the piers, flooding hundreds of houses and stores as well as numerous warehouses and storage buildings, and causing over $1,000,000 in commercial damage in this small section alone. Pleasure and commercial boats were smashed or carried up onto the docks and, in some cases, driven into buildings.
An estimated 500 automobiles were damaged or destroyed. Communication, power, and transportation facilities were seriously disrupted, with hundreds of telephones out of order, power lines down, and several sections of the New York, New Haven and Hartford Railroad flooded out.

(3) All along the shoreline below the city, waterfront homes and beaches suffered severely. Cottages and bathhouses on Hazard and Bailey Beaches were either completely destroyed or driven hundreds of yards inland to the northern shores of Lily Pond and Almy Pond respectively. At Easton's Beach, everything was carried away except the main administration building and some sections of the bathhouse. Huge chunks of cliff and shore along

the eastern side of Newport Neck were ripped away. Three persons lost their lives as they fled before the waves.

(4) Damage to shore protection structures, such as sea walls, groins, and bulkheads, was comparatively moderate since the majority of them were overtopped by the extreme high tide, but the destruction of the property these structures were intended to protect was extremely heavy. The damage caused by Hurricane Edna, due principally to flooding from the heavy rainfall, was slight. Of the total estimated losses of $2,791,000 sustained at Newport from both hurricanes, about 90 percent is attributable to Carol. The damage from tidal flooding is estimated to total $2,489,000 exclusive of damage to state facilities, military installations, communications and power. Damage figures for these items afforded no locality breakdown.

(5) Possible remedial measures. - The most effective method of protecting valuable shore property such as that at Newport from tidal flooding is by the construction of sea walls. Numerous objections, aesthetic as well as economic, often exist to structures of this type. However, the value of the land and residences may warrant the construction of short sections of this type of protective works. In Newport Harbor, generally a Harbor of Refuge from storms other than those approaching

from the northwest, protection to boats would undoubtedly be expensive. Breakwaters and jetties afford defense from normal storms and wave action, but when overtopped by hurricane tides their effectiveness against wind and wave is nullified. Some protection to shore property and commercial establishments in Newport Harbor might be furnished by the construction of bulkheads and sea walls, but a detailed survey of the area would be required to determine the extent and feasibility of such a project.

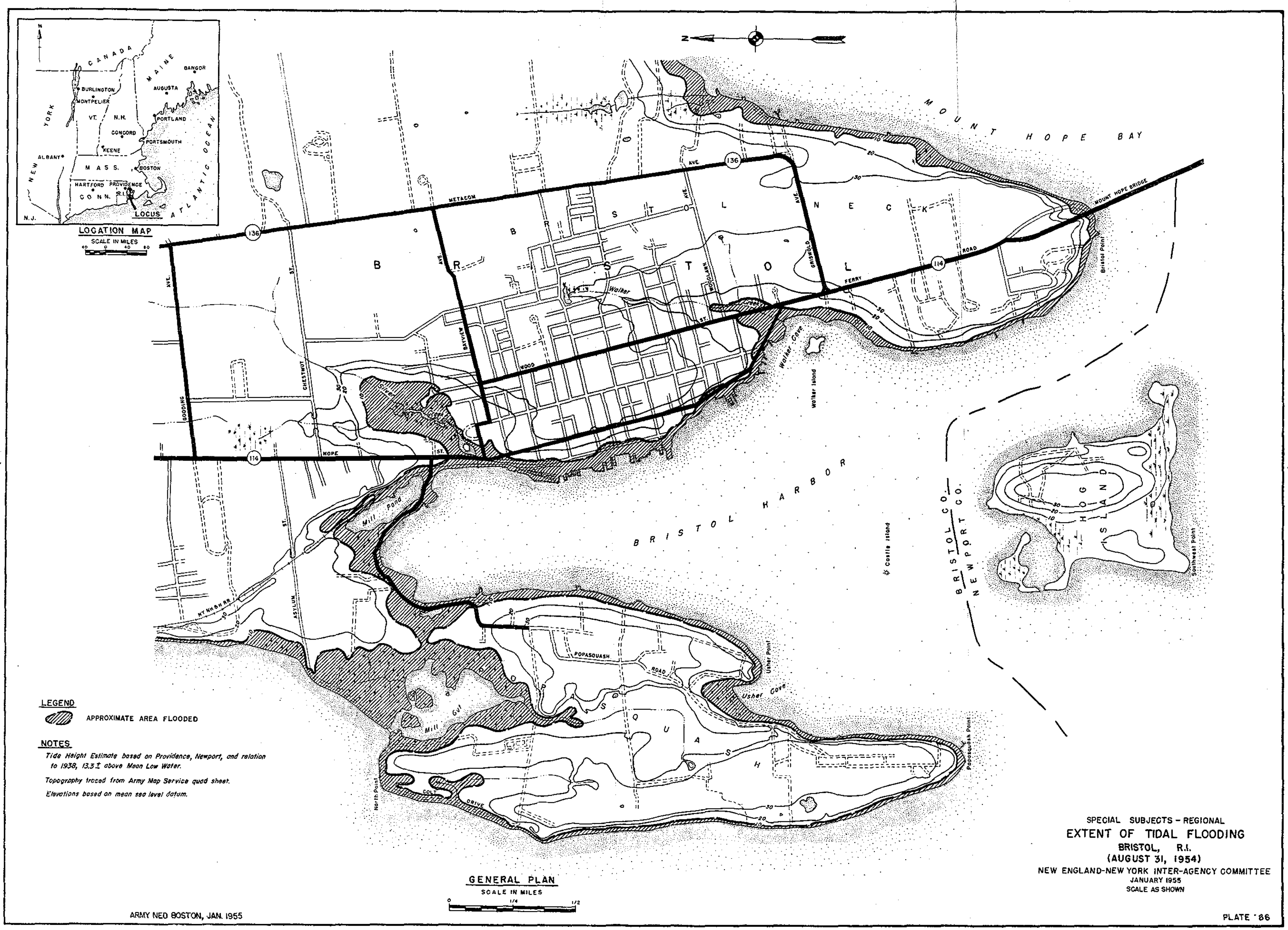
d. Bristol, Rhode Island, area flooded. - The town of Bristol, with a population of 12,320 in 1950, is located on Bristol Harbor, along the eastern side of Narragansett Bay, four miles south of Warren and about 16 miles southeast of Providence. The area subject to tidal flooding consists of the land and property along the shore of Bristol Harbor, which is two miles long, 1.3 miles wide at its mouth and 0.4 mile wide at its northern end. The major flood damage is sustained by docks, warehouses, a railroad yard, several industrial establishments, and a boatyard on the east side of the harbor near the center of Bristol. The extent of tidal flooding is shown on Plate 86.

(1) Cause of flooding. - Severe tidal flooding is caused principally by a combination of hurricane winds and the normal high tide. The mean range of tide is about four feet. However, during Hurricane Carol, the tide reached an elevation of 16 feet above mean low water, or about

one-half foot below the height of the September 1938 hurricane. Shore and harbor protection works are not extensive, consisting of low sea walls and bulkheads. The town of Bristol, lying along the east side of the harbor, is susceptible to damage from storm winds approaching from the south and southwest. Such were the conditions during Hurricane Carol.

(2) Extent of damage. - More than 15 homes were destroyed or badly damaged by the wind and waves, as were many stores and a yacht yard. Public buildings, a state armory, and a fire station were flooded. Private enterprises and commercial establishments, such as restaurants, garages, automobile dealers, shell fish boats and sheds, were hard hit. Public and private piers and waterfront buildings were battered by loose buoys that were washed up from the Coast Guard Wharf where they were being reconditioned. A railroad yard, located in the northwest corner of the town, was flooded and many rails were damaged. Also suffering severe flood damage were a lumber yard, a furniture storage building, and industrial equipment. Boat damage was heavy on this side of the harbor and extremely severe at the Bristol Boat Yard in the northwest corner of the harbor. A low, marsh area north of the town at the upper end of the harbor near the mouth of Silver Creek was extensively flooded, and remained under water for a considerable length of time due to clogged culverts and poor drainage.

(3) Bristol's water supply, the source of which is the Warren Reservoir in Warren, was shut off due to salt water contamination and



CHAPTER XXXIX

a broken main. Many sections of the town were polluted with oil from ruptured petroleum storage tanks. Damage to sea walls and roads was sporadic, some being completely destroyed, while others were unaffected.

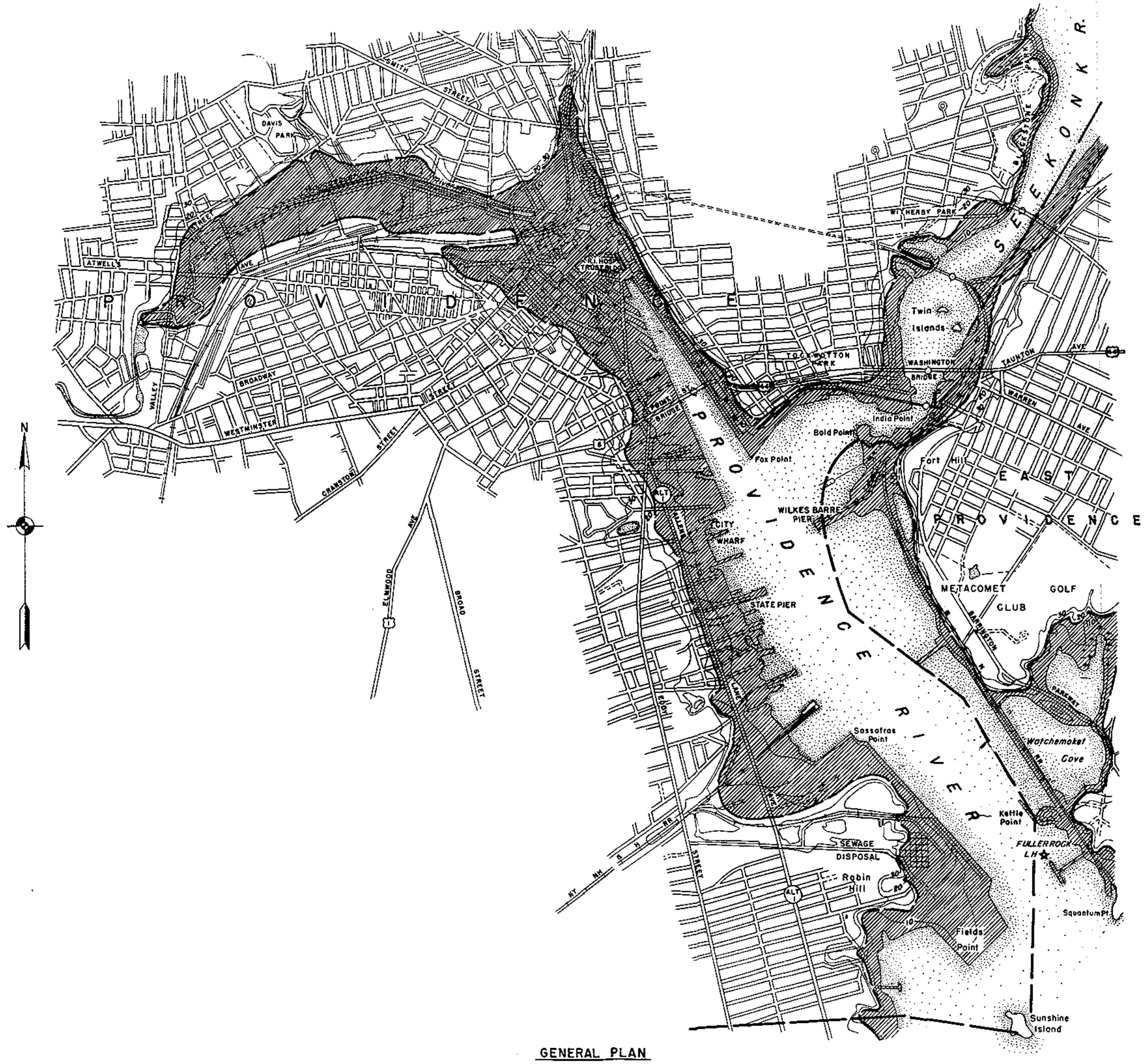
(4) It is estimated that the total amount of damage sustained in the Town of Bristol was about $3,182,000, of which 96 percent was attributable to Hurricane Carol. The damage from tidal flooding was an estimated $2,609,000 exclusive of damage to State facilities, railroads, communications and power. Damage figures for these items afforded no local breakdown.

(5) <u>Possible remedial measures.</u> - Several proposals to reduce future damages from tidal flooding are under consideration by the town officials and by the Harbor Improvement Committee. Consideration is being given to the feasibility of constructing breakwaters, raising several existing sea walls, and relocating the state armory. Plans are being formulated for filling in the marshland in the low Silver Creek area, and enlarging the culverts and other drainage works. A detailed survey would be required to determine the extent and economic feasibility of protective measures.

c. <u>Providence, Rhode Island, area flooded.</u> - The city of Providence, with a population of 248,674 in 1950, is located in the area where the Woonasquatucket and Moshassuck Rivers join to form the Providence River, at the head of Narragansett Bay. The area subject to flooding includes the Providence waterfront area and much of the heavily concentrated business area in the center of the city. In this area particularly, stores, banks, restaurants, and thousands of automobiles were inundated during Hurricane Carol. Plate 87 shows extent of tidal flooding.

(1) Cause of flooding. - Tidal flooding at Providence occurs when hurricane winds synchronize with normal gravitational high tide. The mean range of tide is about four and one-half feet. During Hurricane Carol, the tide reached an elevation 13 feet above mean high water, or slightly less than a foot below that attained during the September 1938 hurricane. Winds of a sustained velocity of 90 miles an hour were recorded with gusts exceeding 100 miles per hour.

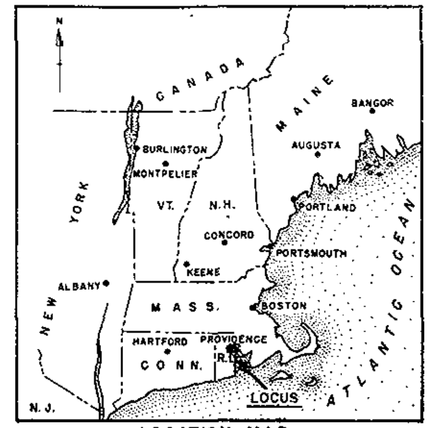
(2) Extent of damage. - The damages caused by Hurricane Carol at Providence were among the heaviest experienced in New England. Commercial losses alone are estimated at almost $40,000,000. Telephone service was seriously disrupted and electric power in the city was almost completely shut off, causing large quantities of food to spoil from lack of refrigeration. With four to five feet of water in downtown Providence, thousands of parked automobiles were submerged and thousands of office workers were marooned in the upper floors of buildings. Although many lives were lost in Rhode Island, most of the fatalities occurred along the coast and none in this city. Damages to industrial plants and equipment, estimated at over $10,000,000 were also extremely heavy. One rubber company suffered a loss of $1,000,000. Several producing chemical plants lost much of their stockpiled materials from flooding, and manufacturers of



GENERAL PLAN

SCALE IN MILES

1/4 0 1/4



LOCATION MAP

SCALE IN MILES

40 0 40 80

LEGEND

APPROXIMATE FLOODED AREA

NOTES

Tide height 17.0' ± above Mean Low Water at R.I. Hospital Trust Building.

(.6' below Flood of 1938)

Topography based on U.S.G.S. Map.

Elevations refer to M.S.L. Datum

SPECIAL SUBJECTS – REGIONAL

EXTENT OF TIDAL FLOODING

PROVIDENCE, R.I.

(AUGUST 31, 1954)

NEW ENGLAND-NEW YORK INTER-AGENCY COMMITTEE

JANUARY 1955

SCALE AS SHOWN

ARMY NED BOSTON, JAN. 1955.

jewelry and machinery suffered severe corrosion damage to their machines, equipment and finished products. The total estimate of damage at Providence, from both hurricanes, is $52,725,000. Of this, almost $51,000,000 was attributable to tidal flooding which occurred during Carol. These figures are exclusive of damage to State facilities, railroads, communications and power. Damage estimated for these items afforded no locality breakdown.

(3) Possible remedial measures. - Several plans have been proposed to prevent or reduce damages from tidal flooding in Providence. The possibility of constructing a dam across the Providence River at one of several possible sites has been suggested. There appear to be various possible dam sites, the most northerly being upstream of Point Street Bridge, and the most southerly being at the lower end of Narragansett Bay. In general, the more northerly sites offer protection to less extensive portions of the area, and would require larger pumping stations, but would conversely necessitate lesser provisions for navigation. The more southerly sites have the advantages of protecting successively larger areas and requiring less extensive provisions of pumping stations, but would involve far more extensive provisions for navigation. Some possible sites and their broad requirements are outlined below. Several variations of these plans of protection have been suggested and should be investigated.

(a) The first site is just upstream of the Point Street Bridge. An earth dam at this site with flood walls extending to high ground on either side would provide protection to downtown Providence. Since the storage area would be very limited, this plan would require a large pumping station to remove the run-off above the dam, and gates to permit discharge of normal run-off. The effect on navigation, however, would be negligible since the piers and wharves above Point Street Bridge are not used extensively.

(b) A second plan which has received consideration proposes a barrier at Tockwotten Street, approximately 800 feet below Point Street Bridge protecting the large thermal electric plants as well as the center of the city. A dam at this point would contain two taintor gates to permit the outflow of the normal run-off from the 75 square miles of drainage area above the dam. Pumps, installed at the dam, would be provided to remove the impounded water at times of extreme high tides.

(c) A third plan is for a dam at Fields Point, 2.2 miles below the Point Street Bridge. A dam at this location would protect all of Providence, and about 50 percent of the East Providence waterfront. Provisions for navigation and for pumping out the upstream flood run-off would be required.

(d) Another possible dam site is at Sabin Point, about two miles below Fields Point, and just upstream of the mouth of the Pawtuxet River. A dam at this location would be longer, and store more runoff than a dam at Fields Point, but it would protect Providence, most of East Providence and most of the Edgewood section of Cranston. It would require provisions for navigation. It would require the use of a smaller pumping station than would be required at Fields Point.

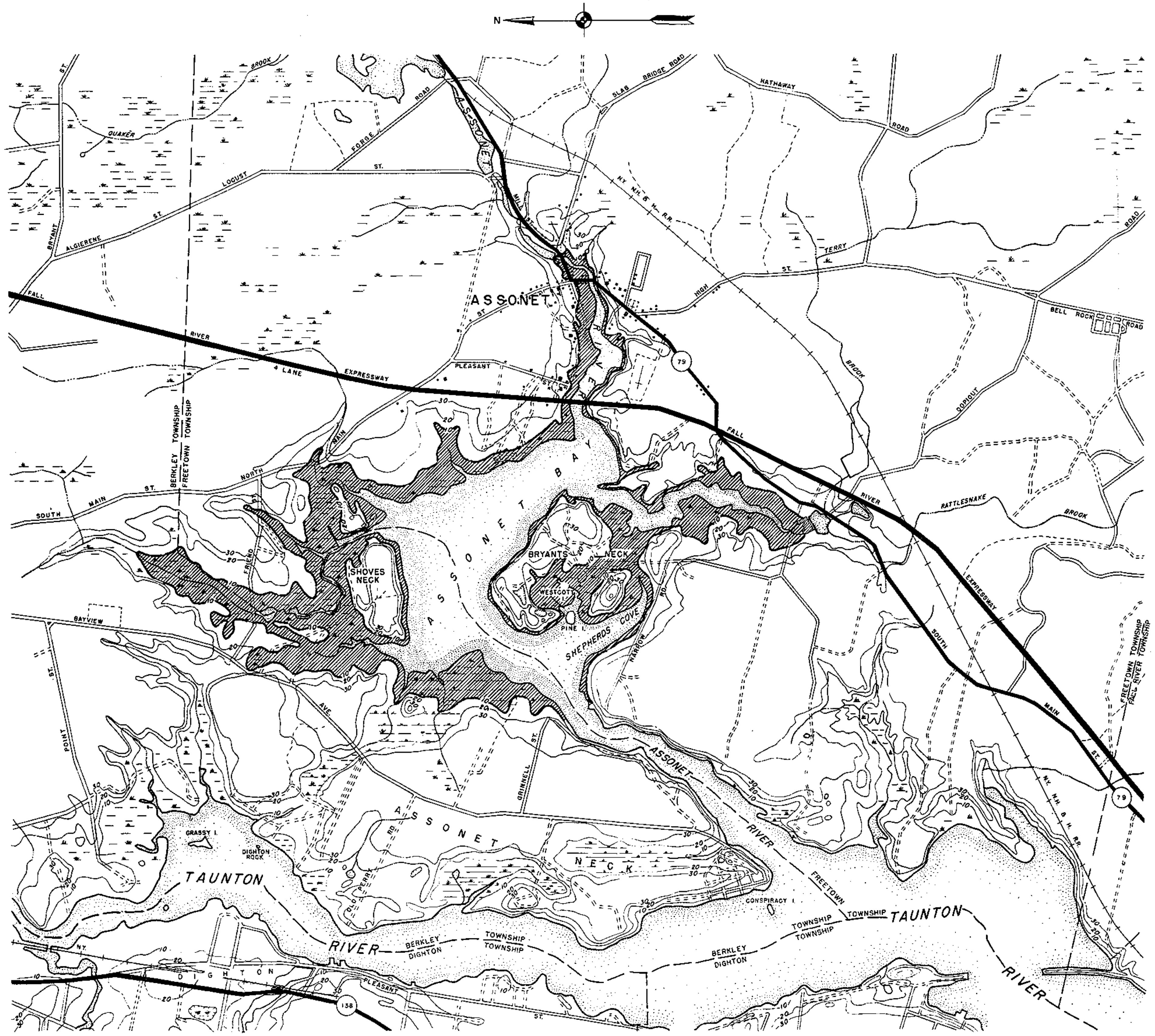
(e) A dam across Narragansett Bay at Conimicut Point would provide protection for Providence, East Providence, Cranston, and parts of Barrington and Warwick. The Pawtuxet River might be diverted across a low neck of land into Apponaug Cove, thereby eliminating the need for a pumping station. Provisions for navigation would be required.

(f) Another possible site is at Patience Island, where a series of dams between Warwick Point and Popasquash Neck in Bristol would further increase the protected area. Provisions for navigation would be needed at this location, in both the East and West passages of Narragansett Bay.

(g) The most southerly dam which has been suggested would close off the lower end of Narragansett Bay and protect Newport and Quonset Point as well as the other communities in the bay. However, the necessary length of the dams, and the extent of navigation facilities needed to handle large naval vessels might well prohibit consideration of this site. Other factors such as pollution in the bay and the effect of the structure on fish life would require extensive investigation.

(4) Costs and benefits. --Any protective measure for the Narragansett Bay area in general and for the city of Providence in particular would consider the relative advantages and disadvantages of each of the proposals described above, and in addition would consider other means for protection. In general, the cost of the bay closures will be found to increase as the protected area increases. Consequently, no particular proposal appers to be more favorable than another at this time. Damages from Hurricane Carol totalling almost $51,000,000 from tidal flooding in Providence and extensive flood damage in the surrounding communities indicate that protection is desirable. Extensive study will be required to determine the type, location, and amount of protection warranted. This is a problem which will require the cooperation of municipal, state, and Federal authorities as well as that of private citizens. It is recognized that the development of dam sites for protection of Providence, as described above, would have effects on marine sport fisheries. Fishery interrsts should be consulted during the planning phases for such construction.

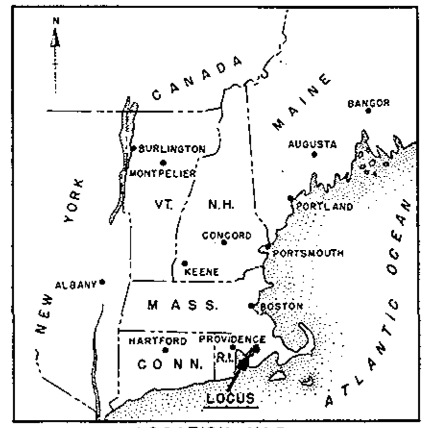
f. Assonet, Massachusetts area flooded. - Assonet is a municipality situated on the Assonet River immediately upstream from Assonet Bay, which empties into the Taunton River at Somerset, Massachusetts. Immediately downstream from Assonet, the Boston-Fall River expressway crosses the river on a causeway and



GENERAL PLAN

SCALE IN MILES

0 1/2 1



LOCATION MAP

SCALE IN MILES

40 0 40 80

LEGEND

APPROXIMATE AREA FLOODED

NOTES

Elevations refer to M.S.L. datum.

Topography based on U.S.G.S. Map.

Flood height based on flood elevation at Providence, R.I.

SPECIAL SUBJECTS - REGIONAL

EXTENT OF TIDAL FLOODING

ASSONET, MASS.

(AUGUST 31, 1954)

NEW ENGLAND-NEW YORK INTER-AGENCY COMMITTEE

JANUARY 1955

SCALE AS SHOWN

ARMY NED BOSTON, JAN. 1955.

PLATE 88

CHAPTER XXXIX

three-span bridge. Plate 88 shows the extent of tidal flooding.

(1) Cause of flooding. - Tidal flooding occurs at the time of extreme high tides accompanying a southeasterly wind of hurricane intensity. Under these circumstances on the low-lying community is inundated.

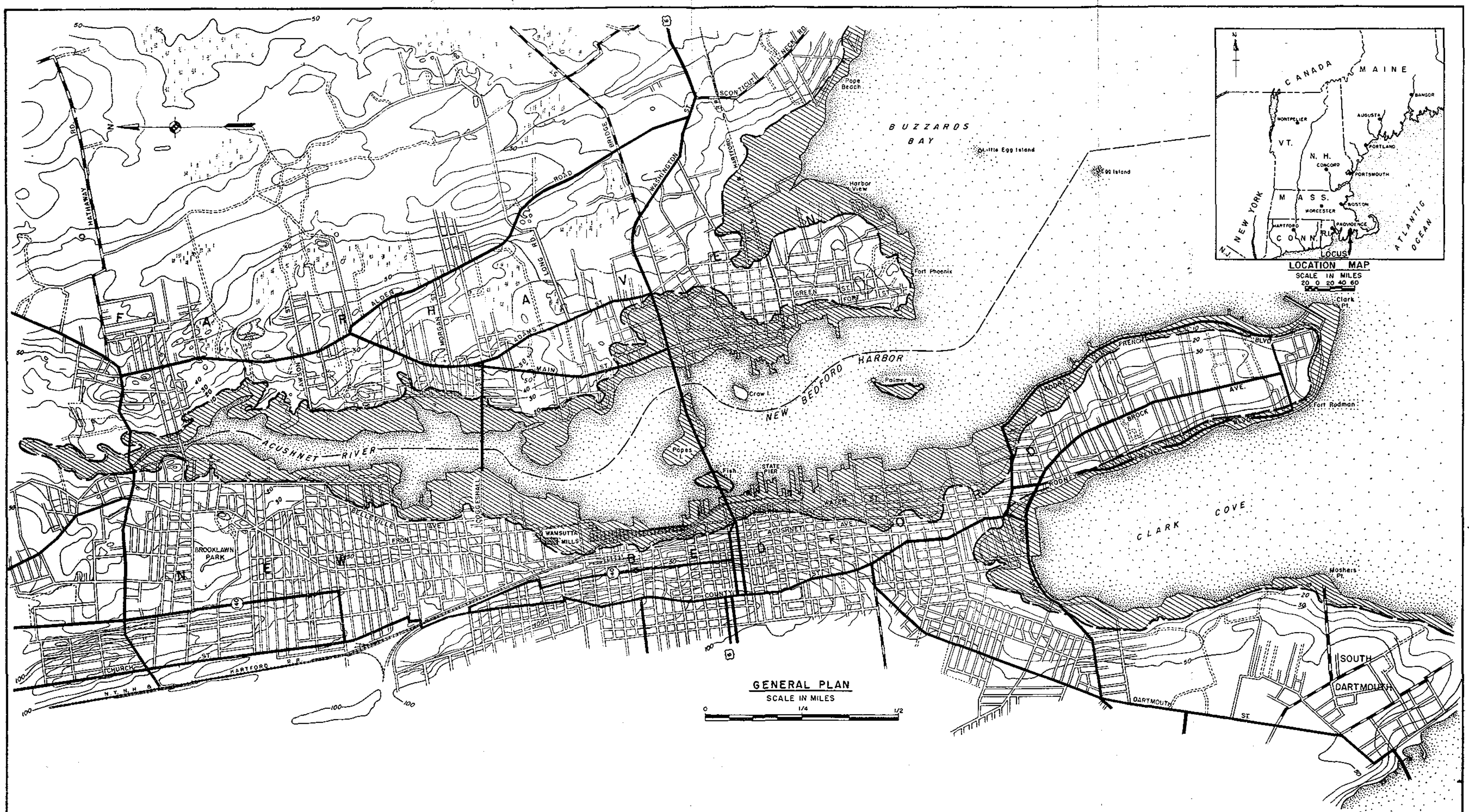
(2) Extent of damages. - During Hurricane Carol, the tide rose to a height of four feet in the post office and along the main street of the village, inundating a considerable section of Assonet and causing damages estimated at about $100,000.

(3) Remedial measures. - Local interests desire the elimination of future tidal flooding and suggest the construction of a tidal barrier at the bridge located downstream from the town. This river crossing consists of a causeway with a three-span bridge, the center span 44 feet wide for the waterway area, and two 50-foot end spans. The lowest elevation of the superstructure is 30.7 feet, mean sea level, which is sufficiently high to enable construction of a dam to protect against abnormal tides. Sluice gates would be required in the dam to control the flow of the Assonet River which at this point has a drainage area of 23 square miles. The area of the reservoir behind such a dam would be only 22 acres, lying between the proposed structure and an existing dam at Assonet. Due to the negligible amount of storage, it would be necessary to provide a pumping station of considerable magnitude to prevent flood damage from interior runoff.

(4) No detailed investigations have been instigated to determine the probable cost of the dam and control works. However, preliminary study indicates that the damages computed on an annual basis would be insufficient to warrant further investigation of the suggested structure.

g. New Bedford-Fairhaven Harbor, Massachusetts area flooded. - This harbor is a tidal estuary on the western side of Buzzard's Bay. It comprises an outer and inner harbor and the tidal portion of the Acushnet River. The harbor separates the city of New Bedford on the west from the town of Fairhaven on the east. The mean range of tide is 3.7 feet and the spring range 4.6 feet. The shorefront property along the entire harbor is subject to tidal flooding with the heaviest damages occurring to the highly industrialized section of New Bedford, two miles in length and about one-quarter mile in width extending northward of a point midway between the New Bedford-Fairhaven Bridge and the Coggeshall Street Bridge. The extent of tidal flooding is shown on Plate 89.

(1) Cause of flooding. - Tidal flooding of the industrial area has been recorded since 1815, with flood heights ranging from 5 to 11.6 feet above mean high water. The greatest heights have occurred when winds of hurricane intensity have coincided with a near full gravitational tide. Tidal flooding in 1938 and in 1954 inundated piers, wharves and warehouses, and damaged machinery and industrial, commercial, and private property. High winds combined with flood tides to wreck ships and to damage bridges



LEGEND

APPROXIMATE AREA FLOODED

NOTES

Tide height taken by Corps of Engineers at;

Wamsutta Mill, bronze plaque 13.7' above M.L.W.

Clarks Point-Fort Rodman Carpenter's Shop 12.81' above M.L.W.

Topography traced from Army Map Service quad sheet.

Elevations refer to M.S.L. Datum.

SPECIAL SUBJECTS-REGIONAL

EXTENT OF TIDAL FLOODING

NEW BEDFORD & FAIRHAVEN, MASS.

(AUGUST 31, 1954)

NEW ENGLAND-NEW YORK INTER-AGENCY COMMITTEE

JANUARY 1955

SCALE AS SHOWN

ARMY NED BOSTON, JAN. 1955.

and buildings. The highly industrizlized waterfront area along the Acushnet River was extremely hard hit by Hurricane Carol. This section contains textile mills, clothing factories, metal working establishments, rubber products plants, and chemical plants.

(2) The industrial losses, alone, from Hurricane Carol are estimated at over $13,000,000 with three plants, two textile mills and one large factory for brass products, each suffering damages in excess of $1,000,000. Direct losses to the New Bedford fishing fleet amounted to about one-half a million dollars, which does not include the consequent loss in business. Commercial establishments, mostly located inland of the industrial area, suffered damages estimated to exceed $1,500,000. The preliminary assessment of losses to private property showed that about 500 homes were destroyed or damaged. The total damages from both Hurricanes Carol and Edna are estimated at close to $22,000,000, with 95 percent due to Hurricane Carol. The damage from tidal flooding is estimated to total $16,537,000, exclusive of damage to state facilities, military installations, railroads, communications and power. Damage figures for these items afforded no local breakdown.

(3) Possible remedial measures. - Local interests, particularly the industrial firms situated above the New Bedford-Fairhaven Bridge, desire protection from tidal flooding. Following

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the hurricane of 1944, consideration was given to proposals to construct breakwaters at the harbor mouth, primarily to protect small boats or to erect a dike with flood gates across the southern portion of the harbor to prevent the entrance of tidal flood waters. A preliminary study indicated at that time that local protective dikes and walls would provide protection to industrial property but that the benefits from such works were not sufficiently wide-spread to warrant construction. A more recent proposal, made at a meeting of New Bedford city and industrial officials following Hurricane Carol and Edna, considered construction of a causeway at the Coggeshall Street Bridge, damaged during Hurricane Carol. A weir, with crest at about high tide elevation, would be included as an integral part of the causeway thus maintaining a permanent fresh water pool behind the barricade. The weir would be bridged by the roadway, and provisions would be made to close this opening against hurricane flooding. This structure would prevent upstream navigation but no great use has been made of this stretch of the river for several years. Further studies would be necessary to to determine the advisability of providing a pumping station to discharge the internal flood runoff, caused by the intense rainfall which so often accompanies a hurricane, and to ascertain the economic justification for the proposal.

161. In addition to the measures which might be employed to protect shore areas from serious tidal flooding, there is an apparent need for additional protected harbors in New England-New York waters. Such harbors would provide safe anchorage for many more boats during the more frequent, severe storms of less than hurricane strength. Although these harbors could not provide complete protection against a hurricane, some partial benefit should result even under those extreme conditions.

162. It is notable that the largest damage to recreational craft occurred in the State of Rhode Island which encompasses the Narragansett Bay area. This large body of water forms one of the notable areas in New England for recreational boating. Despite the popularity of the bay, very little development of harbors for refuge has been accomplished by the Federal or State Governments. Federal navigation projects for the benefit of recreational boating have been authorized for Bullocks Cove and Wickford Harbor. The latter project was completed in 1949. Further study of recreational boating in Narragansett Bay with a view to providing protected shelter for this class of navigation is desirable and appears to be adequately warranted.

162a. It has been suggested that the following locations represent some of the sites which might be suitable for developing harbors of refuge to protect against hurricane damage in the coastal waters of Massachusetts: New Bedford, Quisset Harbor, Vineyard Haven, North Bay at Osterville, Sagamore, Jones River at Kingston, Boston Harbor, Marblehead, and the Annisquam Canal. Other locations at which protection might be accomplished are to be found along the coasts of the other New England States and New York. Small boat harbors and harbors of refuge for these coastal areas are discussed in the chapters on Special Subjects for Subregions "A", "B" and "E".

CONCLUSIONS

163. Of the three hurricanes which entered the New England-New York Region in 1954, Hurricane Carol was by far the most destructive in the region and caused the largest number of fatalities. Rhode Island and Massachusetts suffered by far the heaviest losses. Carol was comparable in intensity and destructiveness to the hurricane of September 1938, but, due to better preparedness, the number of lives lost was small as compared to over 500 lives lost in 1938.

164. The losses in the region from 1954 hurricanes, as given herein, total $305,818,900 with incomplete estimates for damages in interior areas. About 75 percent of this figure is attributable to Hurricane Carol. The major portion of the total of losses was sustained in coastal areas of New England and Long Island from the combination of wind, rain, and tidal flooding. Rhode Island and Massachusetts, which have southern coasts susceptible to tidal flooding, suffered about 70 percent of the 1954 hurricane damage recorded for the region. Table 100 summarizes 1954 hurricane experience.

165. Hurricane experience in the New England-New York Region has not been sufficient to suggest any probable frequency of occurrence. The record of hurricanes which have involved the region points to a seasonal concentration of occurrence in the months of

Table 100 - Summary of 1954 hurricane experience, New England-New York Region

	Path and area affected	Damage by State	
Hurricane Carol (August 31, 1954)	Center crossed eastern Long Island, moved northward into Southern New England passing just west of Worcester, Mass. and continued on through New Hampshire. Area affected - principally eastern L.I. and Conn., R.I., eastern Mass. and N.H. and western Maine.	Connecticut -	$ 28,168,750
		Rhode Island -	97,965,900
		Massachusetts -	92,992,900
		New Hampshire -	4,128,750
		Maine -	5,675,000
		New York -	6,312,500
Hurricane Edna (September 11, 1954)	Center crossed Martha's Vineyard and Cape Cod, then northeasterly offshore passing close to Eastport, Maine. Area affected - principally Cape Cod and eastern Maine.	Connecticut -	4,766,000
		Rhode Island -	5,672,400
		Massachusetts -	10,887,100
		New Hampshire -	1,369,250
		Maine -	8,756,000
		New York -	1,296,000
Hurricane Hazel (October 15, 1954)	Center entered southwestern part of region passing between Buffalo and Syracuse and on over Lake Ontario. Area affected - principally New York State, south of Lake Ontario.	New York -	5,704,200
		Connecticut -	147,150
		New England -	100,000
		Combination of storms or states -	31,877,000
		Total	$305,818,900

1954 hurricane damages by type 1/

Loss of life -	between 77 and 82
Public property -	$53,822,200
Shipping -	12,881,000
Utilities	39,193,900
Transportation -	2,800,000
Commercial -	55,167,500
Industrial -	38,074,500
Agricultural -	29,285,100
Foods & Drugs -	7,278,800
Fisheries -	3,786,900
Private property -	59,670,000
Other 2/ -	3,859,000
Total	$305,818,900

1/ Estimates incomplete for damages in interior areas.

2/ Inseparable combinations of two or more types of damage.

August, September and October, but does not show any recurring pattern. It can be noted that hurricanes have occurred in successive months and in successive years and that periods of concentration have occurred. However, these interesting parallels do not exhibit an over-all pattern of occurrence. To evaluate the chances of hurricane occurrences or probable frequency at a given site for the New England-New York Region would require continuing research. Until a determination of probable hurricane frequency is made, a meaningful estimate of average annual damage at a particular location cannot be made.

166. The greatest damages from hurricanes in the whole region occur as a result of the tidal flooding which accompanies hurricanes in coastal areas. Protective measures against tidal flooding might be justified in coastal areas with high property value. Other preventive, protective and rehabilitation measures include improved hurricane warning systems and dissemination of warnings to the public, evacuation and shelter plans coordinated by responsible State and local groups, coordinated plans for the employment of auxiliary communication and power facilities, zoning and building code revisions and provisions for easing the financial burdens occasioned by hurricane losses.

167. In general, the floods which often result from the heavy rainfall accompanying hurricanes would be protected against to a

high degree by the flood control measures already authorized in the major river basins in New England. On the other hand, there are essentially few practical measures other than the stiffening of building codes which can be employed to prevent widespread damage from abnormally high winds.

PLAN

168. The following plan of measures to cope with hurricanes is suggested:

a. Wider and more expeditious distribution of hurricane warnings and advisories.

b. Research to determine the risk of extreme hurricane wind or tidal effects at definite locations, whether or not they have in fact been subjected to the experience.

c. Information programs to familiarize the public with the nature of hurricanes, existing warning services, and possible protection measures.

d. Radar installations for precise tracking of hurricanes on a radio frequency of about 2800 megacycles with a peak power output of about a million watts, in a system with units at Eastport, Maine; Nantucket, Massachusetts; Atlantic City, New Jersey; Hatteras, North Carolina; Charleston, South Carolina; and Daytona Beach and Miami, Florida.

e. Studies to determine the economic feasibility and desirability of underground placement of power and telephone lines.

f. Studies to determine the desirability, and economic and engineering feasibility of providing protection against tidal flooding in areas which have experienced heavy losses.

g. Studies of individual areas subject to the devastation of tidal flooding to determine what zoning measures might be enacted.

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